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SOME ASPECTS OF RECENT HIGH PRESSURE INVESTIGATION.*

BY

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Twenty-five or thirty years ago the belief was common among chemists that the field of inorganic chemistry was largely worked out, that little of importance remained to be done. This was indeed largely true so long as the methods of chemical investigation were limited to those generally used at that time; but the application of later and more useful methods, and the extension of investigation to a wide range of conditions, have shown that this view is very far from the true one. Indeed, it is now manifest that what is known is but a mere fraction of that which remains to be ascertained; and for the following reason. Until within a very few years, students of chemistry—and for that matter, of physics, too—had occupied themselves almost exclusively with the properties and behavior of matter within a very restricted range of conditions. But, manifestly, if we are to know completely the properties of substances and their relations one to another, we must extend our investigations to cover the whole range of tem-

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* Presented at a meeting of the Section of Physics and Chemistry, held Thursday, October 26, 1916. No attempt has been made to make the list of references complete; many of the papers cited, which are those with which the writer happens to be familiar, give references to earlier work.

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perature and pressure within which each substance is capable of existence. Hitherto the extent of the temperature range studied has been little beyond the boiling point of water, in general; and the sole pressure has been, practically, that of the atmosphere. It follows, therefore, that we have been dealing in the main with a very thin strip of the surface which we may consider to represent the behavior of the substance throughout the range of temperature and pressure within which it is capable of existence. Putting it in another way, one may say that our chemistry has been that of the 25° horizon; but it is obvious that the chemistry of the 250° horizon would differ considerably, and that at the 1000° horizon the mutual relationships would be still simpler—the myriad of organic compounds would then be reduced to two or three, and the complications in inorganic chemistry would be very markedly reduced.

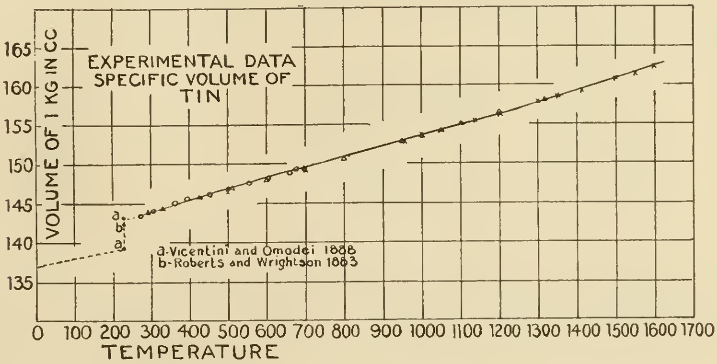
Now since we have investigated such a relatively small part of the whole subject-matter, it is hardly surprising that we should have been unable to detect many thorough-going regularities in the properties of matter; because to discover such regularities it is obviously necessary to make our observations at some kind of corresponding temperatures and pressures—at equal fractions of the critical constants, or whatever may prove to be the corresponding conditions. In any case it is unsafe to assume that ordinary temperature and pressure are anything but arbitrary conditions for comparison. Consequently, to take an example, it is unreasonable to expect that what is known as the law of Dulong and Petit—namely, that the product of specific heat as ordinarily obtained and atomic weight of the elements in constant—should hold for all the elements; indeed, it is surprising that this law holds so well as it does. And, indeed, there is now no question that extended investigation in this sense will increase greatly the scope and utility of chemical generalizations.

In discussing the effects producible by pressure, one must always distinguish carefully between uniform (or pure hydrostatic) pressure and non-uniform compression (which is equivalent to a stress); for the former is incompetent to achieve some of the results which may be brought about by the latter. In what follows we shall always consider the pressure to be uniform, unless the contrary is expressly stated.

I wish now to emphasize the point that changes of pressure and of temperature produce analogous effects—that pressure and temperature are, in chemical parlance, analogous variables. In order to do this, let us consider for a moment what happens when a single crystalline substance is heated slowly.

When heat is slowly supplied to crystals of a single substance the properties (*e.g.*, volume) of the latter change slowly and continuously; but when it has reached a certain temperature, there is an abrupt change of properties and the crystals melt, the temperature at that time being the melting temperature of the solid. Incidentally it may be observed that one cannot determine accurately the melting temperature of a crystalline substance by observing its appearance merely; but must do it by observing the abrupt change in whichever of its properties is most conveniently investigated—*e.g.*, its volume, heat content, electrical conductance. After melting is complete, further addition of heat is accompanied anew by a gradual change of properties, the rate of change of each with temperature being that characteristic of the substance in liquid form. This is illustrated by Fig. 1, which shows the change of specific volume of metallic tin with temperature;[1] the abrupt change in volume at the melting temperature (231.9°) is about 5.5 per cent. of the volume of the solid at that point. Conversely a pure liquid, when cooled slowly (or in such a way as to obviate undercooling), will freeze at a definite temperature to a crystalline solid, with a corresponding abrupt change

FIG. 1.



The change of volume of tin with temperature.

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[1] Taken from the paper of Day, Sosman and Hostetter, *Am. J. Sci.*, 37, 1 (1914).

in properties at that temperature. Now in precisely the same way, such a liquid, kept at constant temperature,[2] and subjected to gradually increasing pressure, will crystallize at a definite pressure—this being the freezing pressure corresponding to the particular temperature. For example, the freezing temperature of water is 0° at 1 atm., −1° at 100 atm.; or one may say equally well, the melting pressure of ice is 1 atm. at 0°, 100 atm. at −1°. Likewise the freezing temperature of mercury is −38.8° at 1 atm., its freezing pressure at 0° is 7600 atm.

Now it may happen that a crystalline substance when slowly heated shows at a definite temperature an abrupt change of properties, but transforms not to a liquid but to a second crystalline form; and on further heating this second form may change to a third or even a fourth, which finally melts to a liquid. An example of this is the substance silica, which shows the following series of changes:[3]

α-quartz	→	β-quartz		575°
β-quartz	→	tridymite	about	870°
tridymite	→	cristobalite	"	1470°
cristobalite	→	liquid	"	1600°

Fig. 2[4] exhibits how the volume of quartz changes when it is heated. In this case the break is neither so large nor so abrupt as it is with metals; but the curve shows without question that a transformation has taken place at 575°, for the volume *diminishes* with rising temperature for an interval beyond 575°. The other three changes run so very slowly that they are not visible on this diagram; the appropriate transition temperatures were fixed by other methods.

This phenomenon—namely, the ability of a chemical substance to appear in more than one crystalline form—is known as polymorphism; and there are many well-known examples of it. Thus, sulphur appears in at least four forms, phosphorus in four, metallic tin in two, calcium carbonate and magnesium metasilicate in three each, and so on. Now polymorphism was quite generally supposed to be a more or less exceptional phenomenon; but we are learning that it occurs very commonly, that so soon as we investigate a substance through a wide range of conditions, we are quite likely to discover that it can exist in more than one form. And just as other forms appear at higher temperatures, so do they appear at higher pressures; the latter case is less familiar to us merely because it has been investigated less seldom. As an illustration, take the substance H_2O, which exists in at least 5 distinct solid forms—ordinary ice, and 4 other varieties, each of which is *denser* than liquid water; to this we revert later.

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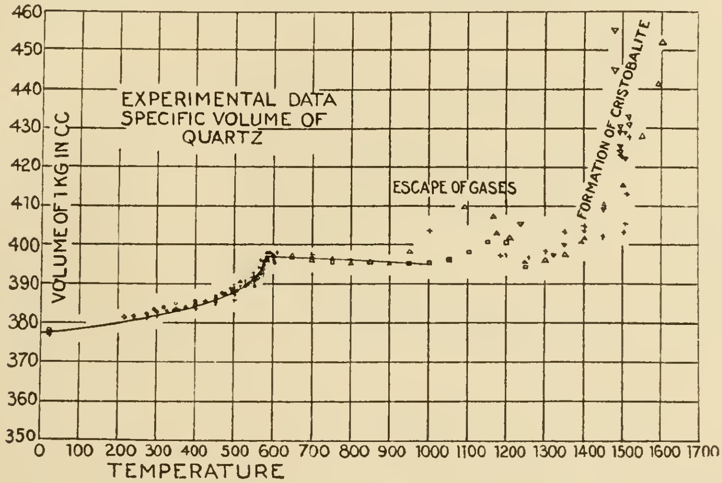
[2] It may be remarked that ordinarily when we speak of melting or freezing point, the assumption of constant pressure is implicit.

[3] See C. N. Fenner, "The Stability Relations of the Silica Minerals," *Am. J. Sci.*, 36, 331 (1913).

[4] Taken from the paper of Day, Sosman and Hostetter, *Am. J. Sci.*, 37, 1 (1914).

FIG. 2.



The change of volume of quartz with temperature.

These examples serve to show the great analogy between the effects of the variables temperature and pressure. Moreover, the fact that the study of a substance through a wide range of conditions frequently results in the discovery of polymorphic forms indicates the great importance of such work to the problem of ascertaining the precise relations between the several forms, crystalline and liquid;[5] and, be it remarked, it is only by varying pressure that we can in such cases study the process through a range of temperatures.

The effects of high hydrostatic pressure upon most properties and phenomena have been very generally overrated, largely because of a confusion of ideas and because it was convenient to have some factor to which one could attribute phenomena not manifestly explicable on the basis of known factors. Indeed, one may say that most of the statements about high pressures usually encountered can be accepted only with considerable reservations, and many of them are altogether misleading—for instance, the assertions that pressure causes certain reactions between solids to proceed. But in some directions the effects producible by high pressures have frequently been underrated. In most text-books one will find the statement that fluids are incompressible; but this is one of those assertions that hold only so long as one does not study the phenomenon too closely. As a matter of fact, the volume of a fluid can be reduced 25 per cent., and that of a solid even can be made appreciably smaller. Fig. 3 shows the change of volume of steel, glass and water by hydrostatic pressure; you see that a pressure of 10,000 atm. (150,000 lbs., or 75 tons, per square inch[6]) causes 100 volumes of steel to shrink to 99.4 vols., and 100 volumes of glass to 97.8 vols. The result for steel is typical of the metals, that for glass is typical of silicates and min-

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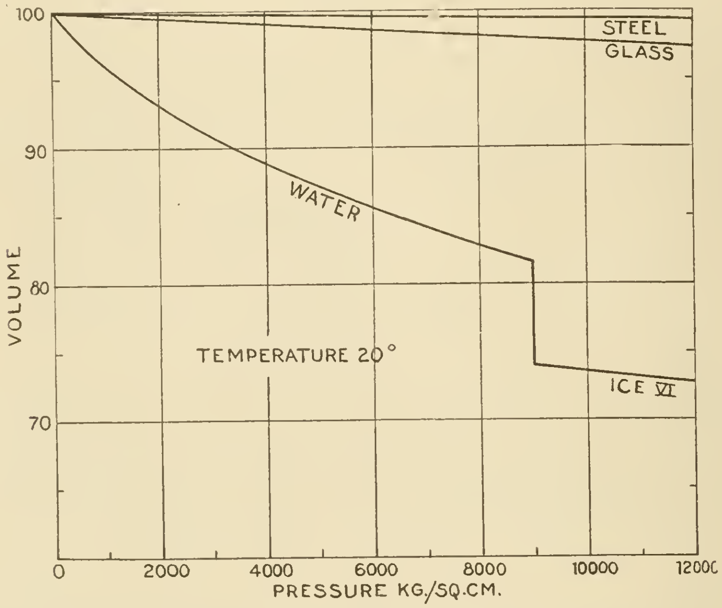
[5] See, in particular, recent papers by Bridgman, *Proc. Am. Acad.*, 52, 57, 91 (1916).

FIG. 3.



The change of volume of steel, glass and water with pressure.

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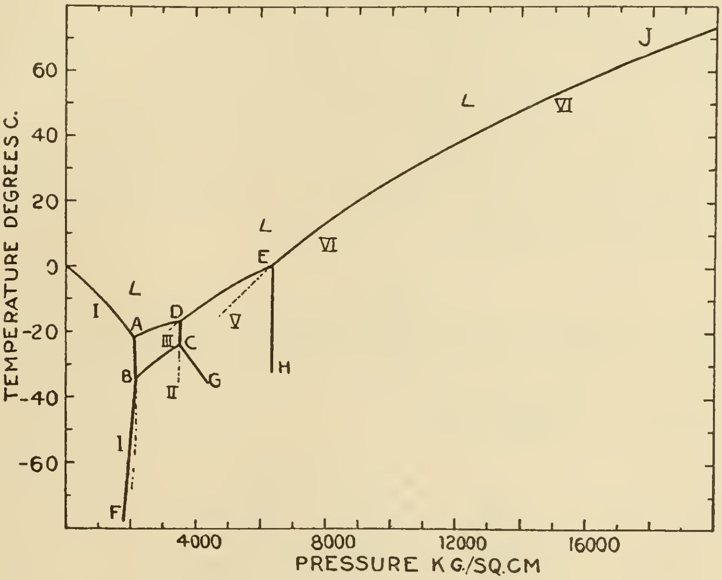
[6] It may be remarked that the pressure in a steam boiler is rarely more than 225 lbs. per square inch, or 15 atm.

erals generally.[7] In the case of water at 20° we see that even 1000 atm. has caused 100 volumes of water to occupy only 96 vols., and that this change of volume goes on progressively—though at a diminishing rate—as the pressure is increased; but at 20°, when a pressure of 9000 atm. is applied, there is a sudden diminution of volume of 7.5 per cent. (of the original volume), followed by a smaller compressibility than before when pressure is further increased. Now what does this discontinuity mean? It means the freezing of the water with the formation of a kind of ice denser than liquid water; that at 20° the freezing pressure of water is 9000 atm., above which pressure we are measuring the compressibility of this form of ice. This curve is typical of all liquids hitherto investigated, for their volume at 10,000 atm. is about 75 to 80 per cent. of their volume at 1 atm.;[8] the pressure at which they freeze differs, of course, from one liquid to another, just as the freezing temperatures at ordinary pressure differ.

FIG. 4.



Equilibrium diagram for water—liquid and five solid forms.

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[7] There are, of course, differences of compressibility from one metal to another, which would hardly be evident on the scale of Fig. 3; for the compressibility is also a periodic function of the atomic weight of an element. (See T. W. Richards, *J. Am. Chem. Soc.*, 37, 1653 (1915).

[8] See Bridgman, *Proc. Amer. Acad.*, 49, 1 (1913).

The similarity between this graph for water and that (in Fig. 1) showing the change of volume of liquid tin with diminution of temperature, illustrates again the point that the variables temperature and pressure are completely analogous. The main difference (which, indeed, depends upon our system of units) is that a change of pressure of 1000 atm. will in general effect no more in condensed systems (*i.e.*, systems without a vapor phase) than a change of temperature of 10°; this is evident from the diagrams, and we shall encounter further examples of it.

The freezing pressure of water at 20° is 9000 atm.; now if similar experiments are made at other temperatures, the appropriate freezing pressures are determined. In this way, or by analogous experiment, we obtain the melting (or freezing) curve of the substance, *i.e.*, the curve which shows the relation between melting temperature and pressure or, if you please, between melting pressure and temperature. In Fig. 4 is given the freezing curve of liquid water, as determined by Bridgman;[9] some of the numerical data are collated in Table I.

TABLE I.

Numerical Data Pertaining to the Equilibrium Diagram for Water—Liquid and Five Solid Forms (After Bridgman)*

Pressure kg. per sq. cm.	Corresponding Temperature	Phases in Equilibrium
1	0.0	Freezing-point: ice I-liquid
1,000	− 8.8	“ “ “ “
2,000	−20.15	“ “ “ “
2,115	−22.0	Triple point (*A*): ice I-ice III—liquid
2,170	−34.7	“ “ (*B*): “ “ —ice II
3,510	−24.3	“ “ (*C*): ice III-ice V—ice II
3,530	−17.0	“ “ (*D*): “ “ —liquid
4,500	−10.2	Freezing-point: ice V-liquid
5,500	− 4.2	“ “ “ “
6,380	+ 0.16	Triple point (*E*): ice V-ice VI-liquid
8,000	+12.8	Freezing-point: ice VI-liquid
12,000	+37.9	“ “ “ “
16,000	+57.2	“ “ “ “
20,000	+73.6	“ “ “ “

*The notation ice IV was not used, as it had already been assigned by Tammann to another reputed form, which differs very little from ordinary ice (I): the existence of this form, which was not encountered by Bridgman, is very doubtful.

As is evident from the diagram, the complete freezing curve is made up of four distinct curves, which represent the equilibrium between liquid (L) and four different kinds of solid water

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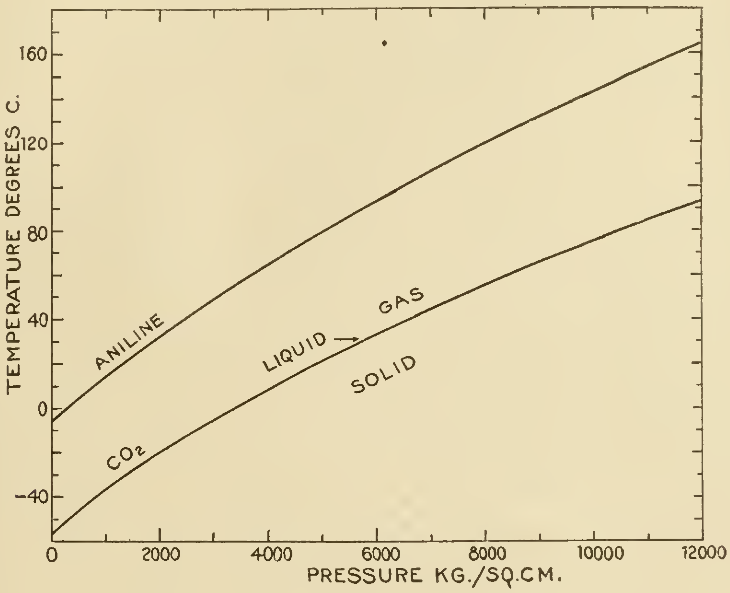
[9] P. W. Bridgman, *Proc. Am. Acad.*, 47, 439 (1912).

(I, III, V and VI). As the pressure is increased from 1 atm., the freezing temperature is lowered, approximately 1° for each 100 atm., in accordance with the fact that the specific volume of ordinary ice (ice I) is greater than that of liquid water; but when the pressure has become 2115 atm., the freezing temperature begins to rise again and we are now dealing with the equilibrium between liquid and another form of ice, a form which is denser than the liquid. Incidentally this shows that the maximum pressure obtainable by cooling water in a closed vessel is 2100 atm., that pipes capable of withstanding this pressure would never burst by freezing of the water. As the pressure is raised beyond this point, the freezing temperature proceeds along the curves AD, DE, EJ successively, each of these three solid forms being denser than the liquid. Again, if we keep the temperature constant at −20° and increase the pressure gradually, the following sequence of events will occur: at 200 atm. ice I will melt, but at 2500 atm. the liquid will freeze again to III; this in turn will at 3500 atm. pass over into V, which at 6300 atm. will transform to VI. At any temperature higher than 0° (the ordinary freezing point of water), no solid will appear until the pressure exceeds 6400 atm., when VI will appear at a pressure depending upon the

FIG. 5.



The melting curves of aniline and solid carbon dioxide.

temperature, *e.g.*, hot water at 73° will freeze to a solid under a pressure of 20,000 atm.

The general type of melting curve is that of ice VI; it is more readily apparent from Fig. 5, on which the curves for aniline and CO_2 have been drawn. The curves are convex to the pressure axis; or, in other words, each successive increment of pressure produces a smaller effect—and indeed, this statement is true generally no matter what be the property in question. This is illustrated also by Table II, in which the numerical data[10] for several substances have been brought together. The actual slope (dT/dP) of the curves differs from one substance to another, but only within comparatively narrow limits—from a few degrees

TABLE II.

Melting-Curves of Various Substances (After Bridgman)

Pressure Kg. Per Sq. Cm.*	Mercury		Potassium		Sodium		Nitrobenzol		Carbon Dioxide	
P	*t*	Δ*t*	*t*	Δ*t*	*t*	Δ*t*	*t*	Δ*t*	*t*	Δ*t*
1	−38.85		62.5		97.6		5.6		−56.6	
		5.10		16.2		8.6		21.9		19.3
1,000	−33.75		78.7		106.2		27.5		−37.3	
		5.09		13.7		8.1		21.2		16.8
2,000	−28.66		92.4		114.3		48.7		−20.5	
		5.09		12.3		7.6		19.9		15.2
3,000	−23.57		104.7		121.9		68.6		− 5.3	
		5.09		11.1		7.2		18.8		13.8
4,000	−18.48		115.8		129.1		87.4		+ 8.5	
		5.08		10.2		6.9		17.7		12.7
5,000	−13.40		126.0		136.0		105.1		21.2	
		5.08		9.4		6.6		16.9		11.7
6,000	− 8.32		135.4		142.6		122.0		32.9	
		5.07		8.7		6.3		16.1		11.1
7,000	− 3.25		144.1		148.9		138.1		44.0	
		5.06		8.1		6.1		15.5		10.6
8,000	+ 1.81		152.2		155.0		153.6		54.6	
		5.06		7.5		5.9		15.1		10.2
9,000	6.87		159.7		160.9		168.7		64.8	
		5.05		7.0		5.7		14.8		9.9
10,000	11.92		166.7		166.6		183.5		74.7	
		5.04		6.6		5.4		14.5		9.6
11,000	16.96		173.3		172.0		198.0		84.3	
		5.03		6.2		5.2		......		9.3
12,000	21.99		179.5		177.2		......		93.6	

* 1 atm. = 1.033 kg. per sq. cm.

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[10] Taken from Bridgman, *Phys. Rev.*, 3, 153 (1914).

up to 40° per 1000 atm.; it is determined at any point by the relation

$$\frac{dT}{dP} = \frac{T\Delta V}{\Delta H} \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

i.e., by the ratio,[11] at that point, of the change of volume (ΔV) on melting to the heat change on melting (ΔH, the so-called latent heat). ΔH is always positive, ΔV is positive for all except two substances—ice I and metallic bismuth—so far as known; accordingly these are the only solids whose melting temperature falls as the pressure is increased.[12]

It is of interest to inquire what is likely to be the course of the melting curve at still higher pressures. Tammann has argued, on an altogether insufficient experimental basis, for the existence of a maximum on the curve, which implies that by the application of *sufficient* pressure all solids could be melted, no matter what the temperature. Now from equation I it follows that there would be a maximum on the curve only if ΔV becomes zero at some pressure; but Bridgman's work shows that ΔV diminishes more and more slowly with increase of pressure but shows no sign of vanishing. Accordingly we believe that the melting temperature continues to rise indefinitely with increasing pressure, although the melting curve becomes gradually flatter and flatter. Again, some writers have expressed the belief that the melting curve has a critical end-point analogous to the critical end-point of the liquid.[13] From thermodynamic principles it follows that the condition for a critical end-point is that ΔV and ΔH should vanish simultaneously, but Bridgman's work shows absolutely no indication of such a thing—indeed, ΔH, instead of tending towards zero, shows rather a tendency to increase at higher pressures. Moreover, it is hard to conceive of a *continuous* transition (as the existence of a critical end-point would require) from the orderly arrangement characteristic of a crystal to the unordered distribution characteristic of a gas.

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[11] It may be remarked that there is no general relation between ΔH and ΔV, for we may have a large latent heat associated with a small volume change, and vice versa.

[12] In the system water, as we have seen, this holds only up to a pressure of 2100 atm., at which point ice I ceases to exist.

[13] This last point is of some general importance, so let us digress for a moment to consider the significance of a critical end-point. If a liquid is heated up in a confined space so that it is in contact with its saturated vapor (*e.g.*, water and saturated steam), the vapor pressure gradually rises; and the properties of the two phases resemble each other more and more closely until at a definite temperature they cease to be distinguishable. For water this happens at about 370° and 200 atm., the density of each phase being about 0.3. The point at which they cease to be distinguishable is the critical end-point of the liquid. At temperatures lower than this, continuous concentration of the vapor will always result ultimately in its condensation to liquid; at higher temperatures no liquid will form no matter what the concentration (pressure) of vapor. In other words, at a definite temperature, the liquid

There is thus, as we have seen, no reason for believing that the melting curve either passes through a maximum or comes to a critical end-point; and it has been found that there is no break on this curve when the temperature reaches the critical temperature of the liquid phase. This is illustrated by the curve for CO_2 in Fig. 5; namely, at a pressure of about 5800 atm. the melting temperature of solid CO_2 has reached 31°, the critical temperature of liquid CO_2; at pressures higher than this the solid sublimes or passes directly into a gas, and the curve then represents the equilibrium between gaseous CO_2 and solid CO_2, though there is, of course, no break at the critical end-point of the liquid. Consequently it is in this case practicable to pass from *gas* (not vapor, for it is above the critical temperature) to crystalline solid merely by change of pressure. This suggests that any gas can be converted into a solid by the application of sufficient pressure, that one could in this way get solid air even at ordinary temperature provided only that the pressure required be not in excess of the maximum which a containing vessel can be made to withstand. And this fact constitutes another reason for believing that the interior of this earth is substantially solid; so that the laboratory evidence, when properly interpreted, yields the same conclusion as that reached on totally different grounds by those who have considered the speed of transmission of earthquake waves, the existence of tides within the earth, and such problems.

Let us now revert for a moment to the subject of polymorphism. The study of the substance water over a wide range of pressures has resulted in the discovery that there are at least five different forms of solid water, the relations between these five being given in Fig. 4. This is perfectly analogous to the case of SiO_2, where the other forms appear at higher temperatures.

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phase ceases to exist. Moreover, by appropriate manipulation of the conditions one can always achieve a *continuous* transformation from gas to liquid.

Thus new crystalline forms may appear at high pressures just as they appear at high temperatures; and in either case, such forms may often persist at ordinary pressure, just as tridymite and cristobalite persist when once they have formed. We may expect, therefore, that extended pressure investigations will yield substances hitherto unobtained or unknown, and that some of these will prove to be of technical importance. In connection with the possibilities in this direction I would point out the new modification of phosphorus recently described by Bridgman.[14] He had heated ordinary yellow phosphorus to about 200° and 12,000 atm., and kept it under those conditions for several minutes when a sudden large drop in pressure occurred; on opening the bomb he found a new variety, much denser (2.7) than either the red (2.3) or yellow (1.9) form; it is grayish-black like graphite, is ignited with difficulty by a match, and cannot be exploded by a blow from a hammer. This substance may not have any technical importance, but its formation—which apparently does not occur except under those extreme conditions—illustrates the possibilities.

We have been considering the effect of pressure upon the state of equilibrium of the several forms of a substance. Now the position of equilibrium determines whether a given change may, or may not, take place under given conditions; but, even though the change is possible, it will not take place unless its rate under the particular conditions is appreciable. In other words, the non-occurrence of a change may be due to a laziness, as opposed to an inability, to proceed under the given conditions. The rate of reaction is therefore an important factor; but whereas it is increased enormously by rise of temperature, it appears in general to be but little affected by change of uniform pressure. Likewise the effect of pressure upon viscosity and similar factors is in general unimportant as compared with the effects of temperature; for a change of a few degrees will exert as great influence upon this type of property of a condensed system as a pressure change of 1000 atm.

Closely allied to this is another point. The transformations of which we have been speaking are reversible, *i.e.,* they will go in either direction depending upon the conditions. But there are other transformations which are irreversible—they will proceed in one direction only. As to these nothing can *a priori* be said; for such transformations take place whenever and wherever their rate becomes appreciable. Consequently the temperature region within which such an irreversible transformation takes place varies with the conditions, especially such as the presence of a solvent; but there is no reason to believe that pressure quickens this process at all. This conclusion is borne out by the fact that high pressure acting on either marcasite or aragonite has been found to be absolutely without effect in inducing the transformation to the more stable pyrite, or calcite, respectively.

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[14] P. W. Bridgman, *J. Am. Chem. Soc.,* 36, 1344 (1914).

On the other hand, pressure may induce some transformations which would not be predicted in advance of experiment. For example, B. H. Hite, working at the West Virginia Experiment Station, found that pressure alone will coagulate albumen, and that—possibly by reason of this coagulating power—it will kill bacteria, yeasts, molds, and other microörganisms. This striking fact may possess considerable practical importance, for, to take an illustration, it was found that a comparatively low pressure of 4000–5000 atmospheres applied for two minutes destroys every pathogenic organism in milk, without altering its odor or taste, though even the very delicate milk enzymes are not impaired.[15]

Hitherto we have considered the effect of pressure upon systems of a single component only—in other words, its effect upon what are usually looked upon as physical changes. Let us now take up very briefly condensed systems of more than one component. The simplest case of this character is the solubility of a salt in water. The influence of pressure upon solubility has been determined reliably only in a few cases, but the results agree in showing that the solubility is affected only slightly, so slightly indeed that the effect [16] is negligible as compared with that of temperature; for the solubility change, which may be either positive or negative, is of the order of 1 per cent. for 1000 atm. Corresponding to this, pressure has but a slight influence upon binary condensed systems generally, and upon the melting temperature and composition of the eutectic mixture in particular; this effect, indeed, is of the order of the present uncertainty in such observations at ordinary pressure, so that we have not yet been able to establish it definitely. That these influences should be small is manifest from the following reasoning. Any chemical equilibrium is determined by the relative concentrations, when a state of equilibrium has been attained, of the several molecular species concerned in the reaction; consequently the position of equilibrium is affected by pressure only in so far as the pressure alters the relative concentrations of the several reacting molecular species. Now since the compressibility of liquids and solids is small, the difference in compressibility (which is a measure of the effect of pressure in altering the relative concentrations) is very small, and consequently the effect of pressure is in such cases very small.

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[15] See the papers by Hite and collaborators: "The Effect of Pressure in the Preservation of Milk," W. Va. Expt. Station Bull. No. 58 (1899); "The Effect of Pressure on Certain Microörganisms Encountered in the Preservation of Fruits and Vegetables," *ibid., Bull.,* 146 (1914).

[16] The change of solubility with pressure at constant temperature $(\partial x/\partial p)$ and its change with temperature at constant pressure $(\partial x/\partial t)_p$ are related by the expression $\left(\frac{\partial x}{\partial t}\right)_p \Big/ \left(\frac{\partial x}{\partial p}\right)_t = \frac{\Delta H}{T\Delta V}$, where $\triangle H$ and $\triangle V$ are respectively the partial heat change and partial volume change accompanying the process of solution.

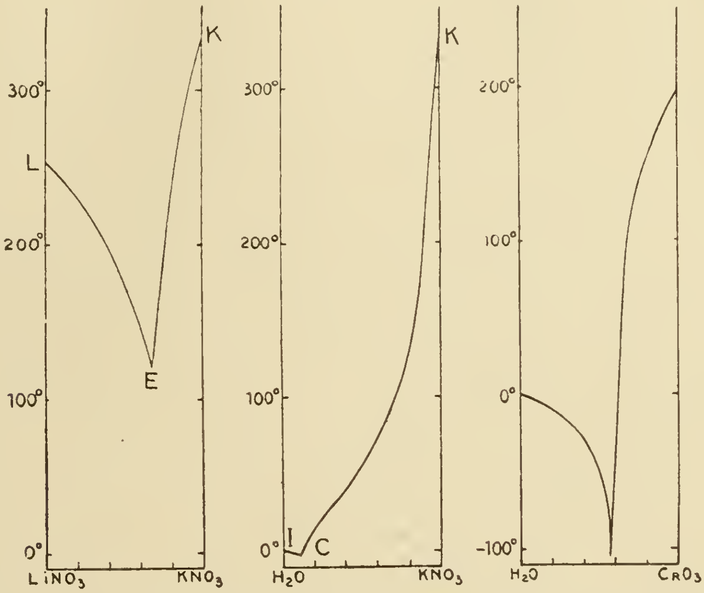
But the effect is of another order of magnitude when a gas or vapor is one of the components; for gases are enormously compressible and their reactivity is practically proportional to the pressure, *e.g.*, at 1000 atm. the concentration of a gas would be substantially 1000 times as great as at 1 atm. As a simple example, consider the amount of calcium carbonate (as calcite) which will dissolve in water enclosed in a vessel with a series of partial pressures of CO_2. The minimum solubility in water at 16° is about 16 parts per million, an amount which is quadrupled by the pressure of as little as 0.0003 atm. CO_2 (3 parts per 10,000, the proportion in outside air), and has increased 70 times when the CO_2 pressure reaches 1 atm. This great increase is an example of the very great effect producible by increase of concentration (partial pressure) of a gaseous component; it is, of course, due to the formation of bicarbonate in the solution, but this circumstance in no wise affects the force of the argument. And this effect is of an altogether different order of magnitude from that of hydrostatic pressure on solubility, the latter being negligible in comparison; and therefore it is manifest that in discussing such effects one must take care to observe whether the pressure is or is not changing the relative effective concentration of any of the components, a distinction which has not always been borne in mind by those who have considered such questions.

A closely related point is that a compound resulting from a reaction involving a volatile component will not be formed unless the concentration—in other words, the partial pressure—of that component is above a certain limiting value, this limit being dependent on the conditions, on the temperature in especial. An illustration may serve to make this clearer. If we wish to keep liquid water at 200° we must have it in a closed vessel capable of withstanding the vapor pressure of water at that temperature, which amounts to about 15 atm. (225 lbs. per sq. inch); likewise at 300° the vessel would require to be strong enough to support an internal pressure of 100 atm.; but if the vessel should leak, either because it was not strong enough or not tightly closed, the vapor would escape and the liquid water would disappear. Similarly we can keep $Ca(OH)_2$ as hydroxide at 550° in steam at 1 atm., but at 750° it would be necessary to have a pressure of water vapor of about 15 atm. (and at 950° about 100 atm.) if we wish to retain it all as hydroxide and to have no oxide present: in other words, if we should wish to prepare $Ca(OH)_2$ from CaO at a temperature of 750°, we could do so only by having continuously a pressure of at least 15 atm. of water vapor above it. A technical illustration of this occurs in the manufacture of salicylic acid, in which dry sodium phenolate is heated at 120°–130° in contact with a few atmospheres, pressure of CO_2, when the following reaction takes place: $C_6H_5.ONa + CO_2 \longrightarrow C_6H_4.(OH)COONa$, the yield being practically perfect; whereas, if CO_2 gas at 1 atm. pressure is used, a much higher temperature (180°–200°) is necessary and the yield is miserable. Nevertheless, there are a number of cases of this kind in which the effects have been attributed to pressure, whereas the real agent is the high temperature at which the process was carried on; in such cases the pressure plays a more or less subsidiary rôle, increasing the yield by securing an adequate concentration of the vapor.

Again, water vapor—or, for that matter, any volatile component—may, and does, act in a way precisely analogous to any non-volatile component, the only difference being that it in general requires pressure in order to hold it on the job, so to speak. As an illustration, let us consider the equilibrium diagrams in Fig. 6, I for the system $LiNO_3$–KNO_3, II for the system H_2O–

KNO_3, III for the system H_2O–CrO_3. In I *L* is the melting point of pure $LiNO_3$, which by admixture of KNO_3 is lowered along the line *L E:* this line therefore represents the equilibrium between solid $LiNO_3$ and liquid mixtures of $LiNO_3$ and KNO_3 of various compositions—in other words, it is the solubility curve of $LiNO_3$ in these mixtures. Similarly *K E* represents the equilibrium between solid KNO_3 and liquid. These two curves meet in *E,* the so-called eutectic point, at which point (132°) a liquid of the composition 45 per cent. $LiNO_3$, 55 per cent. KNO_3 freezes to an agglomerate of the same composition. In II point *I* is the freezing point of water, and *I C* the freezing point of solutions of KNO_3: in other words, *I C* is the equilibrium line along which ice is in equilibrium with mixtures of H_2O and KNO_3 of various compositions. The line *K C* represents the equilibrium between solid KNO_3 and mixtures of KNO_3 and H_2O; the end nearer *C* is the ordinary solubility curve of KNO_3 in water, while towards *K* it would be more logically called the solubility curve of H_2O in KNO_3. The two curves meet in *C,* which in the case of aqueous solutions is usually called the cryohydric point. These two systems are thus obviously altogether similar, the sole difference resulting from the difference in the vapor pressures of H_2O and $LiNO_3$ in relation to the prevailing

FIG. 6.



To show the similarity between the equilibrium diagram of the systems $LiNO_3$—KNO_3, H_2O—KNO_3, H_2O—CrO_3.

atmospheric pressure; namely, that whereas at the temperatures concerned the vapor pressure of $LiNO_3$ is inappreciable, that of water ranges from some millimeters up to many atmospheres. The equilibrium curve (III, Fig. 6) for the system $H_2O–CrO_3$ is included because in form it resembles very closely that for $LiNO_3–KNO_3$; the branch of the curve on the water side is much longer than in the case of $H_2O–KNO_3$, corresponding to the much greater solubility of CrO_3 in water at and below 0°.

At each point on the curve *C K* the liquid in equilibrium with solid KNO_3 has a definite composition and therefore a definite vapor pressure of water which must be maintained in order to secure the appropriate concentration. This vapor pressure becomes equal to 1 atm. at about 120° (the ordinary boiling point of a saturated aqueous solution of KNO_3); increases, as we ascend the curve, to a maximum, which in this case is only 2 or 3 atm., and finally decreases to zero at the point *K*. In systems such as this—namely, in which the liquid may have (under the appropriate conditions) any composition ranging from one pure component to the other—the magnitude of the maximum equilibrium pressure depends mainly on the melting point of the second component; where the melting point is low, as for KOH, the maximum pressure is less than 1 atm.; where it is high, as for potassium silicate, the maximum is some hundreds of atmospheres. Nevertheless, as is evident from the diagram, the lowering of melting point produced by a comparatively small amount of water may be quite large; for it would seem that a lowering of 100° could easily result from the presence of water vapor at pressures less than 20 atm.[17] The great similarity exhibited by these two systems shows that there is no real difference between melting curves and solubility curves;[18] a simple and well-known illustration of this is the fact that the melting point of $CaCl_2$ $6H_2O$ to a liquid of its own composition is merely a particular point on the graph representing the solubility of $CaCl_2$ in water.

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[17] Incidentally it may be pointed out that the circumstance that pure water has a critical point at 370° and 200 atm. is of secondary importance in the discussion of systems belonging to this type. (See Morey and Niggli, *J. Am. Chem. Soc.*, 35, 1089 (1913)).

[18] This point was clearly realized 30 years ago, by Guthrie, the first investigator of eutectics (*Phil. Mag.*, 18, 117 (1884).

In general it is much simpler to consider all such phase diagrams as solubility diagrams, as by so doing it is easier to grasp their full significance and to predict what will happen under specified circumstances.

This whole question of the state of equilibrium in systems containing a volatile component (water, in especial) is a very important one to geochemistry, and to ceramics in particular; but it would be beyond the scope of the present paper to go more fully into it. The available experimental data on this topic are somewhat scanty, partly because the experimental conditions have not been adequately controlled, partly because of the inherent difficulties; the latter, both on the practical and on the theoretical side, have now been largely surmounted. Let us again emphasize the importance of considering whether pressure is in itself the prime factor in inducing a particular change, or is merely subsidiary to the effect of the accompanying increased temperature—in other words, whether the new state is due to a displacement of the equilibrium consequent upon (a) a relative change of effective concentration produced by the pressure, or (b) the change of temperature in itself. In many cases it is difficult to unravel the effects of these two factors, as, for instance, in the production of gasolene from heavier oil at high temperature, or in the formation of a substance like anthracite[19] from cellulose and water at high temperature; and there is moreover always the possibility that we are not dealing with a real equilibrium at all, that the new state is the result merely of the increased rate of reaction induced by the higher temperature.

Hitherto we have considered only the effects of uniform, or pure hydrostatic, pressure; we shall now take up briefly the effects producible by non-uniform compression. This, which is equivalent to a stress (in many cases superimposed upon a smaller uniform pressure), is competent to produce results which may not be brought about by uniform pressure. It is, of course, applicable only to solids; nevertheless, one must watch for it in working at high pressures with systems containing originally a liquid phase because of the possible solidification of the latter under pressure.[20] In working with solids, therefore, one must distinguish carefully between these two; failure to observe this distinction has led to many apparently contradictory statements, and consequently to some confusion. The main difference is that whereas a homogeneous solid body recovers its original dimensions and properties when relieved from a uniform pressure, it is changed permanently by a stress in excess of its elastic limit; the residual effect is evident as a change of shape—a deformation—which is accompanied by a permanent change in several other properties, *e.g.*, in the case of metals, by residual changes in density,[21] strength, electrical resistance, thermoelectric power. That the effects of stress on a crystalline aggregate outweigh those of uniform pressure follows if we identify a deformation under stress with a real partial local temporary melting, on the basis that the stress acts upon the solid but not upon the liquid phase.[22] This hypothesis, which is not in conflict with any direct experimental evidence, serves to correlate a number of observations on the flow of metals and of other crystalline aggregates; a process essentially the same has in recent years been postulated by several English metallographers as a means of accounting for phenomena connected with the important question of the hardening of metals. In this connection it may be pointed out that the circumstance that a solid has been deformed indicates, not that its strength was necessarily small, but that the shearing forces to which it was exposed were great enough to overcome the resistance to deformation offered by the solid; in other words, the fact that a metal has flowed is no criterion of its strength, nor does it indicate that at the time of flow the metal was necessarily liquid as a whole. Indeed, by deformation of a metal its strength may be materially increased, as instanced by the comparative tensile strength of a wire and of the bar from which it was drawn; this circumstance is made use of in making vessels capable of withstanding the highest pressures.

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[19] F. Bergius, *Z. Elektrochem.* 18, 660 (1912); 19, 858 (1913); *Engineering*, 96, 262 (1913); "Die Anwendung hoher Drucke bei chemischen Vorgängen und eine Nachbildung des Entstehungsprozesses der Steinkohle's (pamphlet publ. by W. Knapp, Halle, 1913).

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[20] At ordinary temperature a heavy lubricating oil, such as is commonly used to transmit pressure, will become very pasty at about 4000 atm.; kerosene about 12,000 atm., and even gasolene at about 20,000 atm.

[21] See Johnston and Adams, *J. Am. Chem. Soc.*, 34, 563 (1912); *Am. J. Sci.*, 35, 206 (1913).

[22] This hypothesis, and some of its consequences, have been discussed in previous papers; see Johnston and Adams, *Am. J. Sci.*, 35, 206 (1913); Johnston and Niggli, *J. Geology*, 21, 599 (1913).

It would lead too far to go more fully into this interesting question, particularly as some portions of it are still in controversy; and indeed, they may remain so for some time, as it is very difficult to devise experiments along this line which shall be susceptible of definite quantitative interpretation. The distinction between uniform pressure and non-uniform compression remains, in any case; it may perhaps be emphasized by the fact that an explosive may be subjected to high hydrostatic pressure without exploding, though very little in the way of a stress may suffice to set it off.

This suggests another point upon which there has been some misapprehension. It has been asserted, notably by Spring, that pressure will cause the formation of chemical compounds and alloys from their constituents, *e.g.*, metallic sulphides from the metal and sulphur, etc. But in the first place, Spring's mode of compression was to consolidate the constituents by squeezing them and to file up the resultant block, repeating this process two or three times; and, in the second place, his criteria for establishing the formation of the compound were altogether insufficient. There is no question that a small amount of the compound was formed at the surfaces of contact, but this is not to be attributed to the pressure in itself but rather to the grinding process to which the material was subjected; indeed, the same effect can be more simply observed by grinding the materials together in a mortar—in many cases, merely by bringing them in contact. Again, with reference to the reputed formation of alloys by pressure, it has been shown that such "alloys" are merely agglomerates; and it appears that pressure can favor the formation of but one group of alloys, namely, by bringing into good contact two metals capable of forming solid solution, this process going on very slowly thereafter by diffusion of one metal through the other.[23] We believe, therefore, that pressure in itself does not favor the formation of alloys nor of compounds such as metallic sulphides; indeed, if anything, it hinders such interaction for it raises the melting point of all metals excepting bismuth. On the other hand, a grinding process will achieve results not producible by uniform pressure, a fact consonant with the hypothesis mentioned above; for instance, calcium carbonate (calcite) ground in a mortar[24] loses a little CO_2, whereas there is absolutely no decomposition when it is subjected to high hydrostatic pressure.

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[23] This whole question of the effect of pressure upon reactions between solids is treated at length in another paper; see Johnston and Adams, *Am. J. Sci.*, 35, 205 (1913). With respect to the rate of diffusion in solids, see Van Orstrand, U. S. Geological Survey Prof. Paper 95 G. (1915).

In concluding this sketch of the effects of high pressure let us look at the general type of apparatus required for high pressure work, and at the general mode of experiment. One may say that the main technical difficulties in experimental work in this field have now been successfully overcome—in particular it is a simple matter to obviate all leaks; nor need such work now be more costly than several other types of research work now carried on in many laboratories. It is, of course, not feasible to go into all the little details necessary to insure success, nor into all the variants used by different investigators, so that only the general features of the apparatus which we have used will be alluded to.

First, as to the method of measurement of pressure. Bourdon gauges can be obtained for any pressure range, though, if the range is large, they are not sensitive to small changes of pressure: moreover all of them are more or less subject to the disadvantage that they do not yield the same readings with decreasing as with increasing pressure. Nevertheless for many purposes they are quite suitable, if calibrated against an absolute gauge. The absolute gauge itself may be used; it consists essentially of a piston of known effective cross-section supporting a known weight, but in many lines of experiment it is inconvenient because each movement of the piston is accompanied by a change of volume which, if not compensated, causes change of pressure. The most convenient method of pressure measurement in experimental work is to utilize the fact (first observed by Chwolson in 1881) that pressure affects the electrical resistance of metals, the changes being perfectly reversible and reproducible if the coil of wire has been properly seasoned beforehand; the effect is positive with some metals, negative with others, and so cannot be due merely to the diminution of volume with increase of pressure. The most suitable material for the coil of such a pressure gauge is either manganin or therlo, by reason of their very small temperature coefficient at ordinary temperatures; the magnitude of the effect with a 100 ohm coil is about 0.2 ohms per 100 atm., so that one may readily secure a sensitiveness corresponding to differences of 0.1 atm. The readings of such a gauge show no noticeable time-lag and are independent of the direction from which the pressure was approached. The gauge is calibrated [25] by taking readings at a number of settings of the absolute gauge; the calibration curve is very nearly a straight line at lower pressures, and altogether straight at higher pressures, so that it can be used with some confidence for extrapolation. Its absolute accuracy is limited by that of the absolute gauge; by this means therefore pressures can be determined with all the accuracy necessary. In the actual form of gauge which we have used the coil is set in a cylindrical hole cut in a steel piece, such as is shown in Fig. 7, fashioned so that the gauge may be screwed in at any one of a number of interchangeable positions in the apparatus; the connecting wires are led out through either soapstone (for lower pressures) or marble (for the higher pressures), an arrangement which is both pressure-tight and electrically good.[26]

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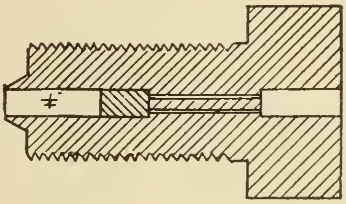
[24] It may be pointed out that very large momentary stresses can be produced when material is ground in a mortar; for 10,000 atm. corresponds to only 1 kg. on an area of 0.0001 sq. cm., equivalent to a square of side 0.1 mm., so that under such circumstances this amount of compression may readily be exceeded momentarily.

FIG. 7.



Pressure gauge. The coil (not shown in the figure) sits within the cylindrical hole at the left; the wires pass out through the block of soapstone or marble.

Pressures up to about 2000 atm. can be developed by means of a simple pump; by combination of such a pump with a multiplying device,[27] pressures up to 5000 atm. can be developed, this being the limiting pressure of the steel tubing that transmits the pressure to the reaction vessel. Pressures higher than this are best developed within the vessel itself by means of a plunger actuated, preferably, by a hydraulic press; and it is well not to have the hydraulic press too powerful, as otherwise it is too easy to burst small pressure bombs, *e.g.*, for a bomb with a hole ½ inch in diameter, each ton of thrust exerted by the press corresponds to a pressure of about 1000 atm. within the bomb.

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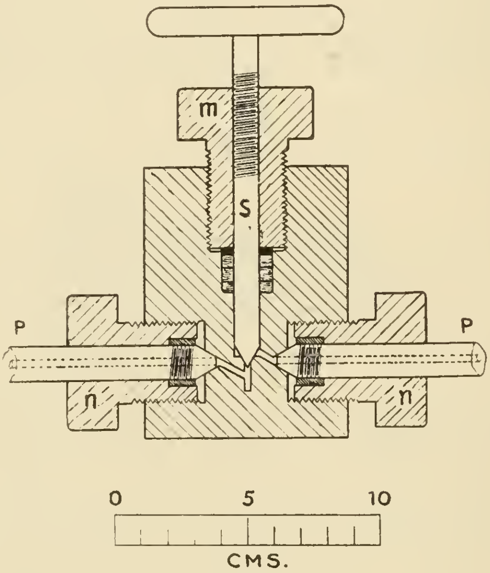
[25] Or it can, of course, be calibrated at a number of previously determined points, *e.g.*, melting pressures of pure substances; this procedure being precisely analogous to the calibration of any form of thermometer at a series of melting temperatures previously fixed by means of a gas thermometer.

[26] An alternative mode is described by Bridgman, *Proc. Am. Acad.*, 49, 640 (1914).

FIG. 8.



Details of high pressure valve and connections, drawn to scale. The main body of the valve is of best quality nickel steel. The conical lower end of the valve spindle *s* fits into a conical depression. The leather packing around the spindle is held down by the nut *m*. On either side of valve is shown the type of high pressure connection which has been used for joining various parts of pressure apparatus. The end of the pressure pipe *p* is turned off at 60° and fits pressure-tight into a conical depression. A small round nut is screwed onto the end of the pipe and the whole is held down tight by means of the larger nut *n*.

Fig. 8 illustrates the type of valve which we have used, and the mode of making connections. The valve-stem *s*, which ends in a cone fitting into a conical depression in the valve block, is kept in place by the nut *m*. The packing consists of three layers of leather surmounted by a steel disk. The pitch of the screw between stem and nut is identical with that between nut and block;

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[27] This consists essentially of a thick-walled cylinder, with a larger axial cylindrical hole at one end than the other, each provided with a tight fitting piston, the two pistons being connected together; by this means the pressure developed at the small end is proportionally greater than that at the large end in the ratio of the effective areas of the two pistons.

by this means one can tighten the nut *m* without jamming the valve down into its seat. The high-pressure connection, which has proved uniformly satisfactory for making all the connections required, is made as follows: The end of the pipe *p* is turned off at an angle of 60°; a small rounded nut with left-handed thread is put on, and the whole held in place by means of the large nut *n* which is undercut to receive the smaller nut. The end of the pipe fits into a conical hole also turned at an angle of 60°; the tip is left, or made, very slightly larger (either by not turning it down completely, or by upsetting it by means of a hammer), a detail which has the effect of insuring that when the end of the pipe is forced into its seat by screwing up the nut *m*, it is the extreme tip that binds on the surrounding metal. This type of joint may leak when pressure is applied for the first time; increase of pressure, however, makes the joint tight by expanding the tip of the tube against its seat, and when this has once happened, the joint remains tight indefinitely. This type of joint possesses the advantages: (1) That it may be taken apart and put together again repeatedly without impairing its efficiency; (2) that it is tight every time and thus obviates troublesome delays due to leaks; (3) that the danger of the whole joint blowing out at high pressure—which may easily happen with ordinary butt joints—is practically obviated, because of the smallness of the bearing surface under all conditions. Moreover all joints are completely interchangeable, and any one of them may be closed off entirely by inserting, in place of the tube, a solid piece of steel similarly fashioned with a shallow small hole drilled axially at its conical tip.

This type of connection and of plug is also illustrated in Fig. 9, which is a sectional drawing of a bomb used for work at high pressures, with the steel piece (Fig. 7) carrying the pressure gauge in place. The essential feature of this bomb, which is copied from Bridgman,[28] is its absolute freedom from leaks at all pressures; this is achieved by the use of a piston so constructed that the effective hydrostatic pressure upon its packing is always greater than that which it is required to hold,[29] and by previously seasoning the bomb in such a way that the hole remains of sensibly the same form and dimensions throughout the pressure range. This is secured by boring a hole, about 1 mm. less in diameter than the final hole is to be, in the block of steel (previously properly heat-treated), making an appropriate plunger, filling the hole with kerosene, and developing within the bomb a pressure of 20,000 atm. or more; by this procedure the hole is bellied-out, the steel deformed and thereby strengthened,[30] so that when the hole is reamed out to its final diameter, the bomb is capable of withstanding satisfactorily repeated applications of pressure of 10,000 atm. or more. The leak-proof piston consists of a hardened steel piece (which fits the hole nicely), surmounted successively by washers of rubber, copper, soft steel and a hardened steel collar which is in contact with the solid plunger actuated by the press; by means of this construction the total thrust exerted by the pressure within the bomb is taken up by a washer of smaller

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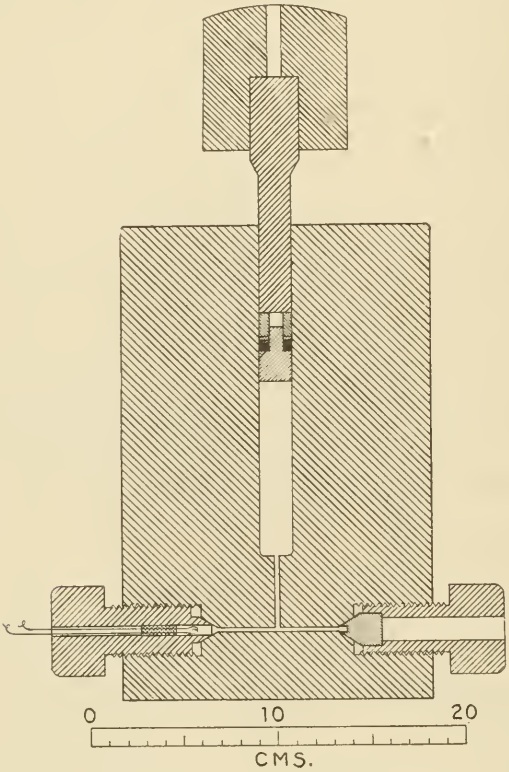
[28] Bridgman, "The Technique of High Pressure Experimenting," *Proc. Am. Acad.*, 49, 627 (1914); q. v.

[29] This is, of course, the principle underlying all successful packings.

FIG. 9.



Sectional drawing of bomb for high pressures, with leak-proof plunger. The pressure gauge is shown in position at the left; the connection towards the right-hand side is closed off.

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[30] I understand that this fact of the strengthening of metal by deformation is taken advantage of in the manufacture of the cylinders for the Ford engine.

area, wherefore the hydrostatic pressure upon the washer is always greater than that within the bomb and no leak of the contents occurs. As an illustration of the absolute tightness of this type of piston, it may be mentioned that the plunger, at a pressure of 2500 atm. within the bomb, returned to the same position within 0.02 mm. when the pressure had been raised beyond 8000 atm. and lowered again to 2500 atm.

For any work at high pressures a previous seasoning of the bomb at a pressure higher than is to be used in the experimental work is essential; without it, there is a partially non-elastic yielding of the metal and therefore a constant liability to leak. With a properly seasoned bomb, a simple rubber washer as packing for the solid plunger suffices for many purposes in which absolute freedom from leak is not essential, *e.g.*, for seasoning the coil of the pressure gauge by exposing it to a pressure in excess of the maximum in its subsequent use. With a seasoned bomb there is a slight elastic reversible yielding with pressure; thus we observed that a cylindrical steel bomb, 4-inch external diameter and 1-inch hole, increased in external diameter about 0.001 inch for each 1000 atm. pressure developed within it.

With apparatus such as has been adverted to, one is now enabled to determine many constants with just as great accuracy at high pressures as at ordinary pressure, *e.g.*, any change which can be recorded by electrical means,[31] or a volume change or a melting, provided that the corresponding temperature is not too high. But if the temperature in question is higher, the metal begins to lose its strength, and the apparatus must be constructed in such a way that the temperature is developed inside the bomb, the walls of which are kept cool. This necessitates a fairly large opening to admit of the electric furnace and heat insulating material, and consequently requires a powerful press to hold the lid on; for instance, if the central hole is 2-inch diameter, and the pressure within it is 2000 atm., the counter-thrust which must be exerted by the press is about 100 tons.

Fig. 10 shows the general arrangement of apparatus[32] with which the melting curve of certain metals up to 2000 atm. was determined; and Fig. 11 represents the central portion of the bomb. The only point to which we shall advert is the method

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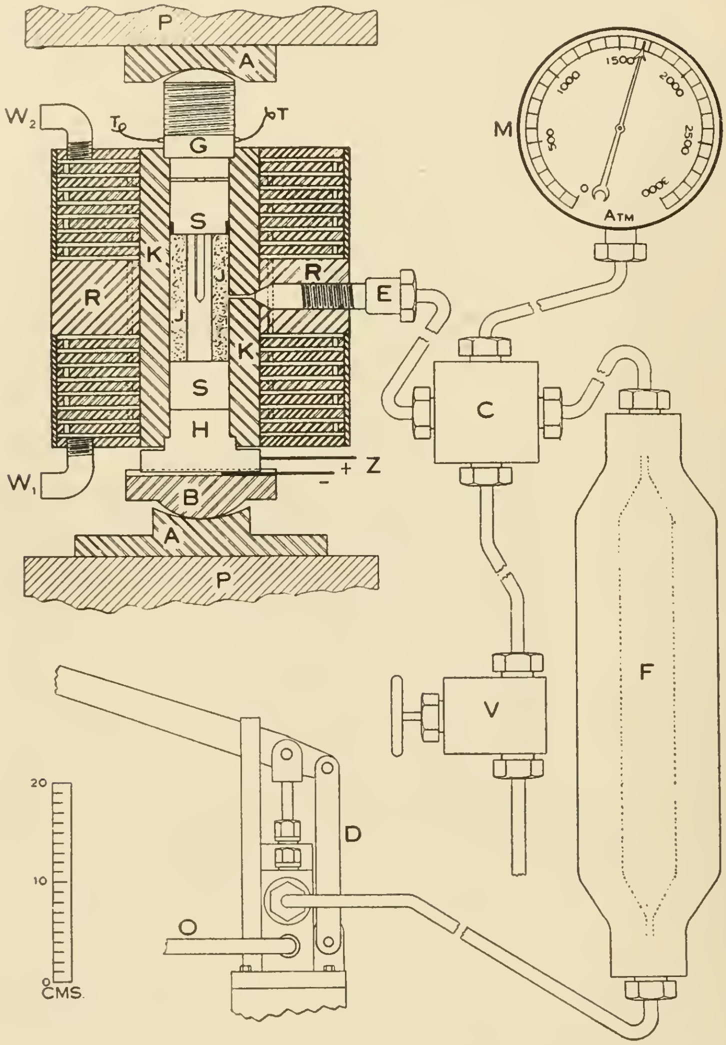
[31] Wahl has by direct optical observations made determinations of physico-chemical constants at high pressures. (*Phil. Trans. Roy. Soc., London,* 212 A, 117 (1912)).

[32] For details, see Johnston and Adams, *Am. J. Sci.*, 31, 501 (1911).

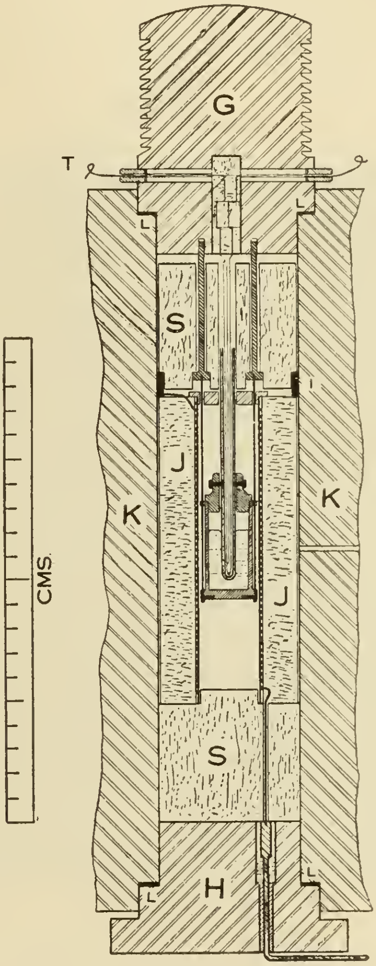
FIG. 10.



General arrangement of apparatus. The bomb is drawn to scale; the rest of the apparatus only approximately so. Pressure is supplied by the pump *D*, and transmitted through the system by means of a paraffin oil which has at the same time a high boiling point and low viscosity. *F* is a steel bottle of about one liter capacity; it serves to increase the volume of the system. The valve *V* (shown in detail in Fig. 8) is used to lower the pressure in the system. *M* is a Bourdon gauge graduated to 3000 atm. in divisions of 50. The connection block *C* affords a 4-way connection between pump, valve, gauge, and bomb. The latter consists essentially of a ring of nickel-steel *RR*, and a number of rings of boiler plate shrunk on to a cylinder of steel KK. On the outside of the rings is shrunk a thin cylinder. The cooling water enters at W_1 and leaves at W_2. The bomb is closed by means of the steel plugs *G* and *H*, which are held in place by a hydraulic press the platens of which are shown at *PP*. The curved surfaces of *A* and *B* on one end and of *A* and *G* on the other constitute the essential parts of the device used for securing alignment of bomb and plugs. *JJ* is the electric furnace (for details see Fig. 11), and *SS* soapstone blocks for thermal insulation at the ends. Thermocouple wires are shown at *TT*, and heating current wires at *Z*.

of closure, which again depends upon the principle of having the packing material subjected to a higher pressure than that within the bomb; this is secured again by concentrating the thrust upon a smaller area. It is effected by making the plug (G or H) of the shape shown and a good fit, and imprisoning the copper washer LL between plug and bomb; this copper washer, which manifestly bears the whole thrust, fills up the space allotted to it

FIG. 11.

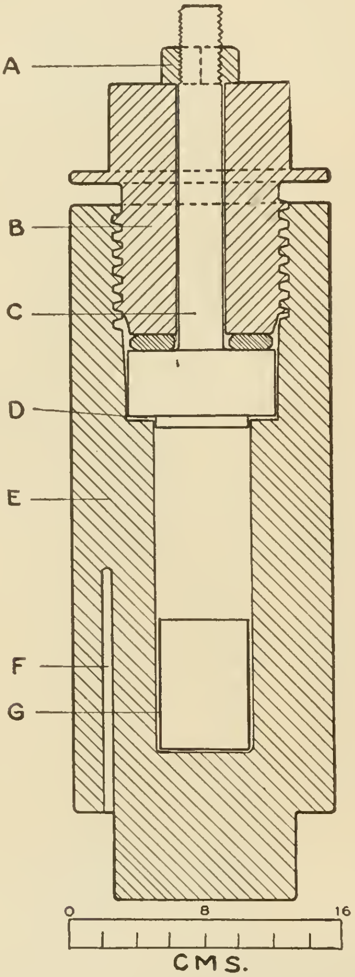


Electric furnace and interior of bomb, drawn to scale. *JJ* is the furnace, *SS* soapstone blocks for thermal insulation of the ends, and *G* and *H*, the plugs which close the bomb. Freedom from leak is insured by the use of the rings or "washers" of sheet copper imprisoned at *LL*. Thermocouple wires *TT* are led into the bomb through the upper steel plug *G*. One terminal of the heating circuit is grounded onto the bomb at *I*, the other passes out insulated through *H*. The graphite crucible with thermocouple tube in place is shown suspended from the upper plug.

but cannot flow away. This type of joint is absolutely tight and has been used in many hundreds of experiments.

For work at temperatures higher than about 400°, oil can no longer be used as the fluid for transmitting the pressure, and one must have recourse to a gas. To work with a gas is much more troublesome than with a liquid, by reason of the very great compressibility of the gas; incidentally the chance of explosion and the damage likely to ensue are very much greater. Several writers[33] have described apparatus which enabled them to reach temperatures of 1000° or higher at considerable pressures (up to 1000 atm.); but for work at high temperatures with high concentrations of water vapor we have found it more convenient

FIG 12.



Drawing of type of bomb used particularly for work with systems alkali—silica—water at temperatures up to 750°. The essential feature is again the leak-proof closure, achieved by means of the copper ring imprisoned at *D*. *F* is a small hole for the insertion of the thermoelement; *G* is a gold crucible to contain the charge.

to proceed in another way, namely, to enclose the other materials with a definite amount of liquid water in a leak-proof bomb which is then heated to the desired temperature long enough to insure the attainment of equilibrium, chilled rapidly and the charge analyzed. For such work, *e.g.*, in investigation of the systems $RO–SiO_2–H_2O$ (where RO represents an alkali or alkaline earth)—it is at the present time more important to map out the whole field than to determine absolutely the coördinates of any one point; the pressure, which is regulated by varying the amount of water, need not be known accurately, though it must be definite, thus necessitating that the bomb be absolutely free from leak.

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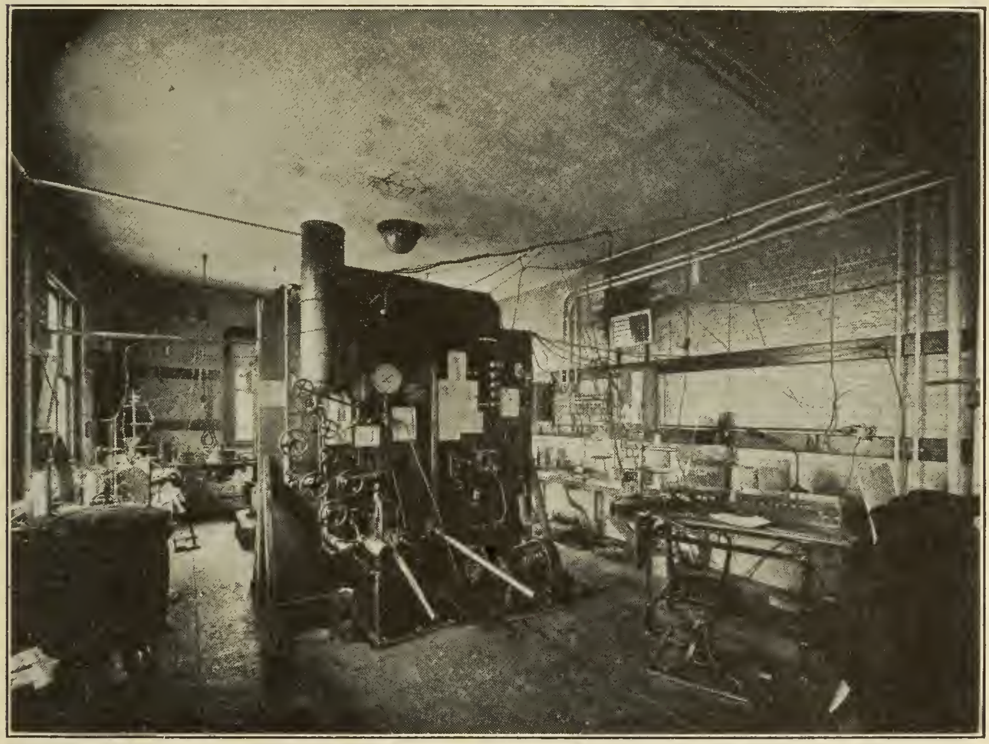
[33] *e.g.*, Hutton and Petavel, *Phil. Trans. Roy. Soc. London*, **A**, 207, 421 (1907); H. C. Greenwood, *Proc. Roy. Soc., London*, **A**, **83**, 483 (1910); Haber, *Z. Elektrochem.*, 21, 89 (1915).

FIG. 13.



General view of apparatus, showing the pump for the hydraulic press, the high pressure pump, and, on the board, the valves, gauges, etc. In the left background one of the bombs and a small part of the press are visible.

Fig. 12 shows the type of bomb [34] which has proved very successful. Such bombs have been used for several hundred experiments at temperatures up to 500°, at which temperature they will hold in pressures in excess of 500 atm.; and numerous experiments have been carried as high as 750°, with pressures in excess of 100 atm. The essential feature is the closure, which is similar to that already described; the general features of the bomb are manifest from the figure.

Figures 13 and 14 illustrate the general set-up of our apparatus.

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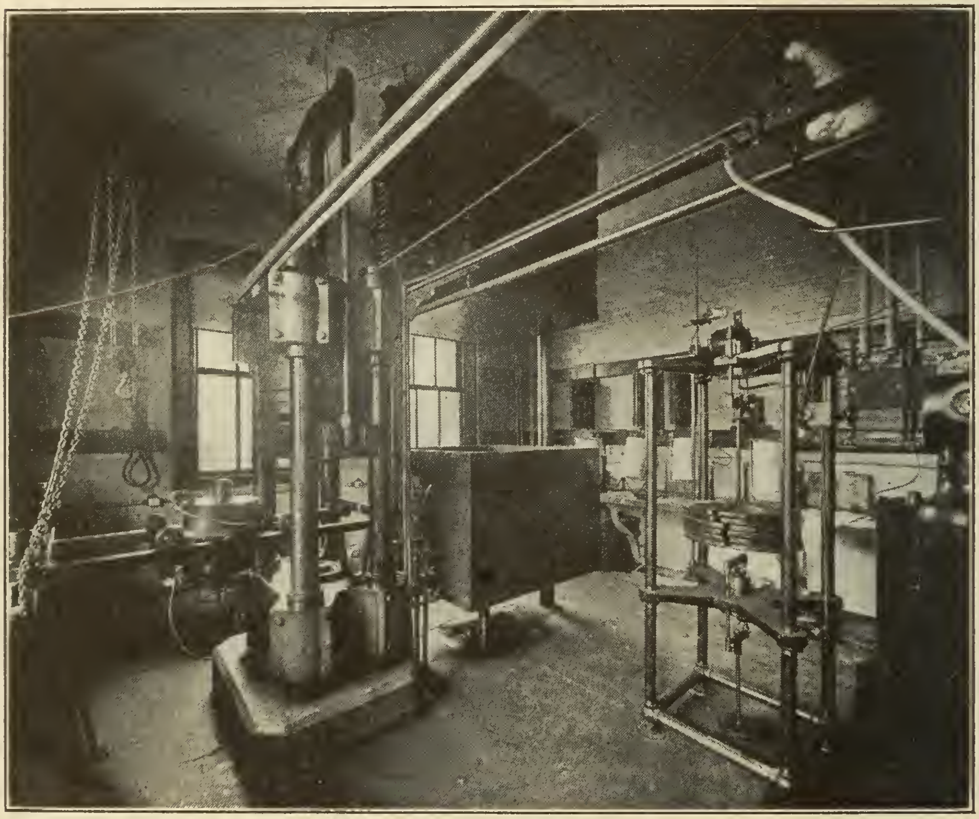
[34] For details see Morey, *J. Am. Chem. Soc.*, **36**, 215 (1914).

RECAPITULATION.

In conclusion, may I recapitulate the points which I have endeavored to bring to your attention. In the first place, chemistry hitherto has been occupied very largely with a very restricted range of conditions; for a complete knowledge of the subject it is requisite that the properties of substances be investigated throughout the range of temperatures and pressure within which each substance can exist. A promising way of investigating the mechanism of certain processes—*e.g.,* the passage from solid to liquid state—is to ascertain the effect of pressure as well as of temperature upon the process; indeed in many cases these two factors cannot be varied independently of one another. Pressure and temperature are completely analogous as variables, though in general a pressure change of 1000 atm. will produce no larger effect than a temperature change of a few degrees.

FIG. 14.



Showing the press and accumulator; and at the right the absolute gauge.

Pressure raises the melting-point of solids (with two known exceptions, ordinary ice and bismuth), the change being successively less with each increment of pressure; but there is no evidence at all for a maximum melting-point or for a critical end-point. Indeed all evidence indicates that by the application of *sufficient* pressure gases would be transformed to solids, a conclusion which is in harmony with that reached on other grounds that the interior of the earth is solid. The effect of pressure upon solubility, and upon condensed systems generally is small; when a gaseous component is present the effect may be very large by reason of the great increase in concentration of the gas produced by the pressure. But many of the effects which have been attributed to pressure are not due to it alone, but often to the high temperature chiefly, the pressure being merely a subsidiary influence; and in such discussion one must always be careful to distinguish between uniform pressure and non-uniform compression as the latter will produce effects very different from those of the former.

Many physico-chemical determinations may now be made with just as great accuracy at high pressures as under ordinary conditions. Apparatus suitable for this purpose has now been developed in several laboratories; some of the apparatus which we have used is illustrated and briefly described.

Nitrate Deposits Disappointing. ANON. (*U. S. Geological Survey Press Bulletin.* No.297, November, 1916.)—Nitrate deposits in many parts of the United States have been examined during the last two years by the United States Geological Survey, Department of the Interior. The importance of finding a natural supply of nitrates within our own borders, which might serve our needs in case of war, has given incentive to this work and has directed widespread public attention to the subject.

Prospectors in many places have raised great hopes by finding good surface showings of these salts, but investigation has seemed to force the acceptance of a general adverse judgment as to their value—a judgment that has been adopted with the greatest reluctance by all concerned. Incidentally, advantage seems to have been taken of the situation to promote certain stock-selling enterprises, even after the evidence as to the worthlessness of the deposits became sufficient to satisfy any competent judge, so that one is forced to question either the good faith of the promoters or their practical judgment.

As a result of careful study of these deposits, and particularly of evidence gathered on recent visits to prospects in different parts of the country, Mr. Hoyt S. Gale, a geologist of the Federal Survey, has submitted the following general summary, which is commended to the consideration of those who are tempted to invest their money in such enterprises.

Fine specimens of practically pure nitrate of soda and nitrate of potash (saltpeter) have been found in many parts of the country, and careful investigation of specimens and localities seems to warrant some definite conclusions as to the practical value of these deposits, especially to those who are invited to spend their money in investigations like those the Survey has already made.

The nitrate salts occur as crusts or films on the faces of ledges; as seams—most of them thin, though some are fairly thick—in crevices of shattered rock; and as deposits filling spaces in porous rocks at and near the surface or extending to a depth of several feet. They are naturally preserved in recesses in the rock ledges, where they are sheltered from the dissolving action of rain, snow water, or even mist. They are found in lava ledges, in beds of volcanic tuff or ash, and in limestone and sandstone. Their existence or preservation is apparently dependent rather on the shattered or porous nature of the rock than on its kind or composition. These deposits, which have been referred to as cave or ledge deposits, are of essentially the same type wherever found, although they vary considerably in details of occurrence.

The incrustations are found not only on the faces and fractures of ledges of solid rock, but some of them form layers or cementing constituents in the loose soil and rock breccia at the bases of cliffs, or lie in places protected from the weather. Some samples obtained from both sources are rich in nitrate salts, and analyses of such materials will bear little significant relation to the actual character or content of the mass of the rock of which the ledge is formed. It appears that the deposits are surficial—that is, they do not extend far into the mass of the rock—and the nitrate salt found is insignificant in amount.

Nitrates are found in unusually large quantities in some soils and in some clay hills, particularly in southern California. These deposits have been examined by many persons and the general conclusion reached has been unfavorable to the idea of their practical utilization. The nitrate content, although unusually large as compared with the content of ordinary soils, probably does not average over 1 or 2 per cent. of the soil or clay, and it is very doubtful whether the material could be worked commercially.

Any one who is not convinced by the judgment already reached as to these deposits and who is determined to devote his time or money to their further exploration should do so with full knowledge of the evidence already in hand and should not be led into such a venture by more or less misleading representations. The Geological Survey will always be glad to make an examination of any samples submitted.

SCIENTIFIC RESEARCH FOR NATIONAL DEFENSE AS ILLUSTRATED BY THE PROBLEMS OF AERONAUTICS.*

BY

LIEUT.-COLONEL GEORGE O. SQUIER, SIGNAL CORPS, U. S. A.,

Member of the Institute.

THE following are some present problems connected with the development of Military Aviation and Aerostation:

I. AERODYNAMICS.

(*a*) Continue the development of the mathematical theory to explain the phenomena recorded in the aerodynamical laboratories, and to forecast further results.

Determine the value of numerical factors for correcting the coefficients observed in tests of small scale models at low air speeds in wind channels in order that these coefficients may be applied more accurately in the design of full scale airplanes.

(*b*) Obtain solutions for the speed and direction of flow of air about geometric and aerotechnic forms, and develop experimental means to visualize or map the speed and direction of flow.

(*c*) Map the currents of the upper atmosphere which may be of most use in aerial navigation, and evolve simple practical rules for the guidance of pilots.

(*d*) Give fuller explanation of the phenomena of soaring, *i.e.,* airplaning indefinitely without motive power.

(*e*) Develop equations and laws of comparison by which the behavior of large aircraft may be more accurately foretold from tests of models. Apply further the principle of dynamical similarity.

(*f*) Investigate more direct and effective methods of securing a lift or thrust in the air from the consumption of fuel.

(*g*) Complete theory of the air-screw.

II. ENGINE PROBLEMS REQUIRING RESEARCH.

(*a*) *Fuel.*—Possibly the most far-reaching problem is fuel. A fuel that will carry more power into an engine per unit volume will be a direct gain.

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* Abstract of an address before the National Academy of Sciences, Boston, Mass., November 14, 1916. Communicated by the Author.

Attempts have been made to combine alcohol, gasoline, acetylene, picric acid, ether, and other hydrocarbons with the above object in view. Questionable results have followed. There has been an increase of power, but nothing so far commercially or practically useful.

This question must be studied with the greatest of care and from a truly research standpoint.

(*b*) *Solid Fuel.*—Solid fuels that can be converted into liquid in small quantities just prior to use are desirable for military aviation. In case of accident from shot or shock, leakage of liquid fuel is a danger. Solid fuel could be carried in quantity with less danger.

(*c*) *Engine Cooling.*—The problem of radiation is important. If some substance could be found that would circulate through the cooling system, at higher temperatures than water, it is probable that greater engine efficiencies would result. Oils, salt waters and other materials have been tried with indifferent success.

(*d*) *Liquid Fuel Pipes.*—Tubing that will resist vibration (causing rupture) is desired. An oil- and gasoline-proof rubber tubing is reported as used in Europe. This development is highly important, not only for tubing, but for containers in which to carry liquid fuel. Some sort of fabric and rubber tank that would really resist the action of gasoline would be of the highest benefit.

A difficulty lies in the fact that the tanks are large (say 20- to 100-gallon capacity). The structural problems would be serious. The tanks now used are large and of metal. Vibration causes much difficulty and leakage.

(*e*) *Metal Coating.*—The protecting of the metal parts of an airplane, especially the fittings and cables, is a serious problem. A material is desired that would really prevent dangerous corrosion. Nickel plating over copper is very good, but will not suffice. Rust strikes through very rapidly. Baked enamel is the best coating. It is impossible to apply in many cases.

(*f*) *Sound.*—The question of eliminating the noises involved in the operation of aircraft is one of importance. The peculiar note of the propeller of a Zeppelin can be heard for several miles, and is usually the first warning of its approach at night.

III. MISCELLANEOUS.

(*a*) *Physiological.*—Study the physiological and psychological effects of low density air at high altitudes on the performance of pilots.

(*b*) *Transparent Wing Covering for Airplanes.*—A wing covering which would answer the following general requirements would be of great value to military aviation:

Weight not more than five ounces per square yard.

It should present reasonably great resistance to flame.

It should be reasonably proof against action of salt water, moist air, extreme dryness and quick temperature changes.

It should not stretch in any direction. Its ability to retain original form as placed on the airplane is very important.

It should have tensile strength of at least 75 pounds per inch width in any direction.

Its tendency to tear and split because of tack holes through it, or because of bullet holes, should be as small as possible.

(*c*) *Development of Light Alloys for Airplane Construction.*—Pure aluminium or aluminium alloys. It is believed that a great deal can be done in this direction. So far no alloy has been developed, except possibly in Germany, which can compare with average Alaskan spruce in its "specific tenacity."

(*d*) *The Structure of Gusts.*—It is believed that this is of sufficient importance to aviation to warrant considerable expense in its study.

Painstaking investigation of the character of eddy formations caused when wind strikes trees, hollows, cliffs, etc., and the character of disturbances created by canyons, swamps, deserts, etc., would be of great value to aviators.

This can be done not only by smoke and toy balloon work in the vicinity of obstructions such as the above, but also by photographic work in wind channels.

A set of simple rules laying down just what the aviator may expect on one side or another of canyons, cities, trees, lakes and swamps would be very helpful in aviation.

(*e*) *Radio-apparatus for Aircraft.*—The subject of radio-intercommunication between aircraft in flight, and between aircraft and the earth requires for its solution the highest possible efficiency and reliability combined with minimum weight.

A present tendency is to entirely separate the power plant from the main engine of an aircraft. The generator body in this case has a stream-line figure and a separate small air-screw is provided. Among other methods the oscillion is being tried as the actual source of continuous electromagnetic waves.

(*f*) *Automatic Devices for Controlling Airplanes.*—The development of large airplanes, with great moments of inertia, has made necessary apparatus which will maintain the airplanes in a stable condition of flight. The basic principle of design of such devices should be such that reactions derived from any disturbance of the airplane from its normal or desired attitude with respect to the relative wind, and with respect to the earth's horizon, will, through the operation of the automatic controlling mechanism, cause the control surfaces to create moments which will return the airplane to its original state of equilibrium. It is suggested that the principle of flight is such that the lateral control (for oscillations about the X-axis), especially, should be automatic.

(*g*) *Bullet-proof Gasoline Tanks.*—Development of a material with which to line or construct tanks to contain the gasoline in an airplane in which a bullet hole will quickly close, entirely or partly at least. This would enable many a flier to get back to his own lines after having been fired upon.

(*h*) *Development of a Fabric as Good as, or Better Than, Irish Linen, for the Covering of Airplanes.*—There has not been manufactured in this country a fabric suitable for use in covering airplanes.

The fabric should answer all requirements laid down under *Transparent Wing Covering,* and be, in addition, such as to shrink the proper amount without harm when cellulose solution is applied.

It is possible that long fiber cotton might be developed that would answer the purpose.

We must become independent in all lines affecting our military aviation. To-day we depend entirely upon Ireland and England for our linen, and the supply is becoming very low in this country.

(*i*) *Aviators' Clothing.*—Much is still to be done in devising non-inflammable and protective clothing for aviators. This question is intimately connected with personal armor and safety in case of fall.

(*j*) *Ground-speed Indicator.*—An instrument which would measure the actual speed of an aircraft over the ground would be useful in the operation of military machines.

(*k*) *Photography.*—The further development of the use of photography from aircraft offers one of the most promising fields of usefulness. A present tendency is to replace manual sketching of trenches, roads, etc., by a series of photographs taken at regular intervals from the moving airplane.

IV. PHYSICS OF THE AIR.

(*a*) *High Frequency.*—At present we have no evidence of vibrations in the air much greater than 40,000 to 60,000 cycles per second, but there is no reason to deny the possibility of vibrations of 100,000 to 200,000 or even a million cycles per second in the ordinary air we breathe. If these vibrations exist, may not they have an important function to perform in nature? The reason, of course, we do not perceive them if present, is because they are above the upper limit of the human ear, and also do not directly affect any of our other senses. Although, in general, viscosity would operate to rapidly damp out these high vibrations, yet the real nature of viscosity at extreme high frequencies is not sufficiently understood at present to be dogmatic. The present efforts of the Master Physicists in regard to the constitution of matter should before long make the securing of high frequency data in air of importance.

Electromagnetic waves of these frequencies existed through all time unperceived until Hertz devised a " detector." At present the detector for high-frequency air vibrations is the manometric flame, and it would be of great importance to invent a detector for air vibrations which would indicate their presence or absence up to 500,000 or a million per second. If we had such a "detector" and also means for producing such vibrations in air, it would be possible to provide a system of intercommunication, over short distances at least, based upon ultra-audible sound waves. We could, for instance, devise a noiseless foghorn as an aid to navigation.

(*b*) *Elasticity.*—The elasticity of the air has been made to serve in a great variety of machines to perform useful work. The original dynamite gun of Zalinski utilized the elasticity of compressed air as the explosive for propelling the projectile.

The best condensers for radio-telegraphy employ air as the dielectric. Any break-down automatically repairs itself and thus adds greatly to reliability.

The passenger automobile itself has been made possible by the development of the pneumatic tire.

(*c*) *Friction.*—The magnitude of the friction of the air against the surface of bodies moving through it may absorb large amounts of energy. The average velocity of shooting stars is 25 miles per second. They vary from 10 to 30 miles a second. The earth's orbital velocity is about 19 miles a second. It is sometimes added and sometimes subtracted from the shooting star's velocity according to the way the body enters the atmosphere. The friction of the air at these velocities is so great as to volatilize metals.

A mass of one gram of air moving with this velocity, 25 miles per second, has a kinetic energy of 8.0937×10^{12} ergs, which is sufficient to lift one ton of matter, 2000 pounds, to a height of 298 feet above the earth's surface. One gram is a small piece of matter to possess this potentiality. This enables us to comprehend, in part at any rate, the disastrous results of the cyclone, where houses and forests are bodily cut down as by a giant steel knife.

(*d*) *Mass.*—A cubic foot of air at 0° C. and 76 cms. pressure weighs .08071 pound, according to Rayleigh. A room 18 × 20 × 10 feet contains 3600 cubic feet. The air in it, therefore, weighs 290.556 pounds. In liquid or solid form this air could be removed from the room with difficulty by a strong man.

On this view it appears that we have been passing our lives on the bottom of a deep ocean of comparatively heavy fluid, and that only recently have we learned how to utilize the dynamic reaction of this fluid to construct machines for transportation freely in three dimensions in the interior of this ocean. Who among us is wise enough to foretell what these machines may yet accomplish?

THE CHARACTERISTICS OF IRON IN HIGH FREQUENCY MAGNETIC FIELDS.*

BY

RALPH BOWN,
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The use of iron magnetic circuits in ordinary electrical generating and transmitting apparatus is so advantageous or more exactly so necessary, that it is at least mildly surprising to find that iron is in many cases worse than useless in high frequency magnetic circuits. So puzzling has been the behavior of the iron under these latter conditions that it has been made the subject of many researches in the past twenty years. Recently the writer took occasion to look up the literature of this research work and found it so extensive and widely spread as to merit the brief compilation which is presented below. The various researches have been considered in a consecutive, semi-historical order and wherever it was convenient the words of the original author have been used. In such cases quotation marks have been placed around the part which is copied verbatim.

The object of the paper is not particularly to comment on the value of any of the work which is cited, nor yet to criticize the conclusions drawn therefrom, but to present a digest of the most important publications which have dealt with the behavior of ferro-magnetic materials when subjected to the influence of high frequency alternating magnetic fields and to point out the more valuable and interesting of the results and conclusions. In a brief summary at the end of the paper the subject is reviewed in a collective way which may be of particular interest to the hurried reader.

THE FIRST EXPERIMENTERS (1827-1900).

As far back as 1827 it was noticed by Savary[1] that a steel needle was magnetized when in the neighborhood of the discharge current of a leyden jar. This was probably the first observation of the effect of an oscillating field on a magnetic material. However, the discharge of the leyden jar was not recognized as oscillatory until in 1842 Joseph Henry[2] demonstrated that needles magnetized by similar discharges varied not only in strength but in polarity as well. The range of electrical knowledge widened so fast in the following years that it apparently interested no one to think further on so relatively unimportant a detail as this "anolomous magnetization" of Henry's until Hertz,[3] in 1888, voiced his views on the matter by saying, with regard to some metal wires which he was using in experiments with very high frequency currents, that iron wires were no exception to the general rule and that the magnetic properties of the iron did not come into consideration with such high frequency oscillations. In the particular experiments of Hertz this was doubtless true, but that the conclusions had no general significance was indicated when J. J. Thomson[4] and some others, in 1891, showed that iron in a rapidly oscillating field absorbs energy which can only be accounted for as a magnetic hysteresis loss, and Trowbridge[5] also in 1891, expressed the opinion drawn from his work that iron is magnetized by high frequency oscillation and that the resulting energy loss increases the damping of the oscillating circuit. Probably this belief had prevailed for some little time in certain quarters, for a theoretical formula was published by Lord Rayleigh[6] in 1886, and by Stefan[7] in 1890, by means of which the high frequency permeability of iron wire could be calculated from separate measurements of its resistance to high frequency and to continuous electric currents. Using this formula as a tool experimenters set out to determine the values which the permeability assumed at various frequencies.

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* Communicated by Prof. Ernest Merritt.

The first of these observers, Birkeland[8] (1893), records his conclusion that "μ decreases with the period of the oscillations." In a more extended investigation in 1893, Klemencic[9] used Rayleigh's and Stefan's formula in the following form:

$$\omega' = \omega \pi a \sqrt{\frac{n \mu}{\sigma}}$$

where ω' = the high frequency resistance, ω = the continuous current resistance, a = the radius of the wire, σ = the specific resistance of the wire, μ = the magnetic permeability, and n = frequency. From measurements made at a frequency of 9×10^7 cycles per second, and with a field intensity "H = 290 Abs. E.," he calculated that μ was 118 for soft iron wires 0.452 mm. in diameter. Slightly later, in 1898, Klemencic[10] published some work on core losses at high frequencies from which the conclusions are somewhat indefinite.

C. E. St. John[11] (1894) compared the self inductions of similar iron and copper circuits and thereby showed that μ must be quite large even for very rapid oscillations. The fact that the high frequency magnetization curve, or the relation between B, the instantaneous flux density and H, the instantaneous field intensity is not a straight line and that therefore average values of μ obtained by experimental methods will depend on the field intensity as well as on other factors, was indicated when Marchant[12] (1900) discovered that the period of an oscillating circuit containing iron varies as the oscillations die out. Marchant believed that this variation of the period was due to the change in the value of μ as H passed through smaller and smaller values and later (1903) he published[13] a graphical method of determining the curve of the oscillatory discharge from a condenser, through a coil embracing iron, when the B-H curve of the core was known.

Before going farther we may briefly mention the Marconi Magnetic Wireless Detector which was announced by Marconi[14] in 1902. In this well-known instrument the received high frequency currents were caused to act magnetically on a piece of laminated soft iron which was continually going through a very slow magnetic cycle. The high frequency magnetic impulses seemed to have the power of altering the shape of the B-H curve for the slow cycle so that the arrival of a wireless impulse was registered by a sudden change of flux in the iron of the detector, which produced an E. M. F. in the recording circuit. Experiments by Piola[15] (1906), Eccles[16] (1906), and Fleming and Coursey[17] (1916) have indicated that the thorough shaking which the magnetic units of the iron receive under high frequency magnetization produces somewhat the same effect on the slowly changing magnetic cycle as is produced by mechanical shocks or vibrations. That is to say, that the oscillations by magnetically jarring the iron allow the impressed field to produce flux changes which would not be produced if the oscillations were absent.

VALUES OF APPARENT PERMEABILITY.

Returning now to the consideration of iron in a single high frequency magnetic field, it may be said that at the beginning of the twentieth century the belief was quite common that magnetic changes of the little molecular magnets of the Weber-Ewing theory were by nature slightly sluggish and that therefore iron was not able to follow rapid magnetic variations as fully as slow ones. This assumption satisfactorily explained the previous experimental observation that the permeability decreased with rising frequency. However, an increasing attention was being paid to the effects of eddy currents and the magnetic skin effect, and investigators recognized more clearly the necessity of considering the form and size of the test piece in interpreting their results.

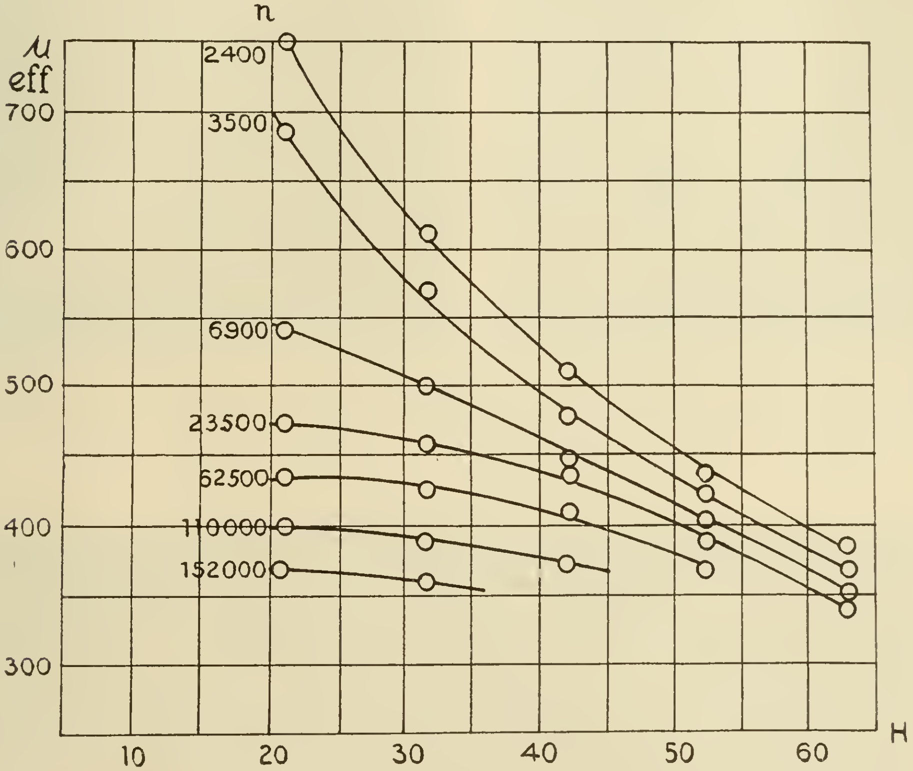
Several of the papers which follow have been abstracted, not because the data which they contain are of any great present value, but either because they have features of special interest or because the conclusions have helped to shape the trend of scientific opinion in this relation.

Varley[18] (1902) used a Braun Tube to determine the maximum values of B and H produced by the discharge of leyden jars through a coil surrounding the test piece of fine iron wires. His data are plotted in curves which indicate that within the limit of his observations (up to 130,000 cycles per second) the B-H curve has the same shape at all frequencies, but that much smaller values of B are reached for a given value of H at the higher frequencies.

Braun[19] (1903) made some experiments with iron powder imbedded in paraffine as a core for the coil of an oscillating circuit vibrating at about 5×10^6 cycles per second. Zenneck[20] (1903) following the method of Braun, showed experimentally that iron powder, the particles of which had diameters ranging from 1.5×10^{-3} mm. to 10×10^{-3} mm., imbedded in paraffine might have much higher permeability and much lower core losses at a frequency of 3×10^6 cycles per second than solid iron wires having a diameter of 0.24 mm. It is stated that the magnetic permeability of iron powder in magnetic fields at a frequency of 10^6 cycles per second is nearly the same as in stationary fields. Battelli and Magri[21] (1906, 1908), by measuring the variation in the period of an oscillating circuit when similar iron and copper magnetic circuits were used alternately, and also by measuring the change in the high frequency inductance of coils with and without iron cores, acquired some scattering data.

Undamped alternating currents were used by Schames[22] (1908). The currents were obtained from a Poulsen arc at frequencies up to 220,000 cycles per second. Two similar coils were placed in series with a hot wire ammeter and so arranged that the voltage at their terminals could be measured with an electrometer. One of the coils had an air core and the other a core composed of a bundle of one hundred soft iron wires 15 cm. long and 0.0051 cm. in diameter each. Measurements of voltage and current in the two coils served as a basis for the calculation of the apparent permeability. The results were shown in the form of curves which exhibit the apparent permeability as decreasing when either the field intensity or the frequency increases. These curves are reproduced here (Fig. 1) because they give some idea of the magnitude of the effects which may be expected when fine iron wire cores are used in high frequency magnetic circuits. In

FIG. 1.



Apparent permeability of fine iron wires as a function of frequency and field intensity. (Schames.)

commenting on Schames' paper *Science Abstracts* says, " As explaining this action an hypothesis is put forward according to which the μ in a rapidly alternating field has not time to arrive at the end value which it would reach with direct or slowly alternating current magnetization. This hypothesis explains also the results obtained by other workers, notably Varley." Zahn[23] (1909) used damped oscillations and from measurements of the high frequency resistance and direct current resistance of steel wires, found a change of the permeability with a change of the current in the wire, which indicated that μ was not independent of H. Later in 1909 Zahn reported work using Schames' method, operating at 2×10^6 cycles per second, on a core composed of thirty iron wires each 0.0494 mm. in diameter. The results when plotted to μ, H coördinates gave a curve very similar in form to the well-known curve for slow magnetization, showing that frequency had but little effect on the relations between μ and H.

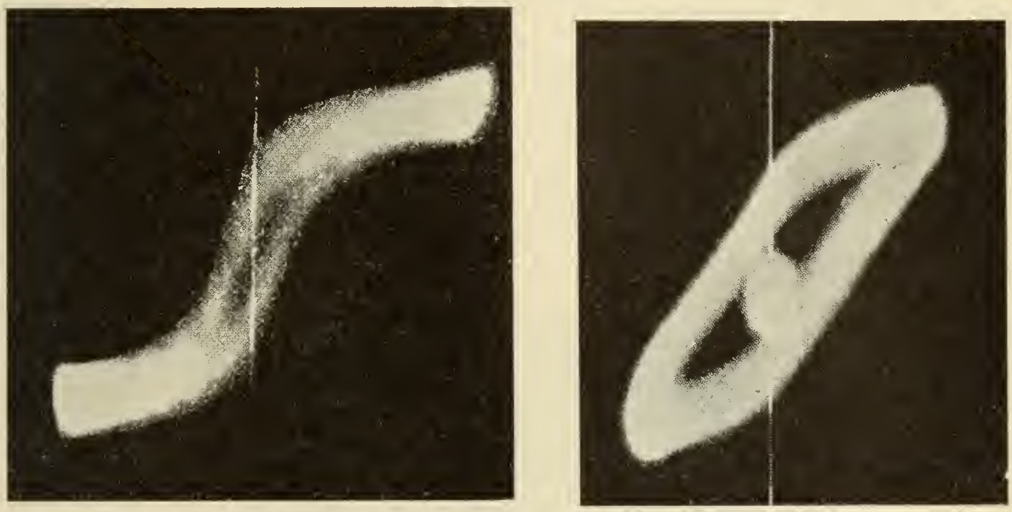
Before considering the effect which the accumulated data began to have on the common conviction voiced in Schames' paper that iron was magnetically sluggish, we may profitably turn to some other researches bearing on the matter.

SHAPE OF THE HYSTERESIS LOOP.

At the same time the work just mentioned was going on, a certain set of experimenters was attacking the question of finding the exact nature of the hysteresis loop which the iron follows when acted upon by undamped high frequency fields. The Braun Cathode Ray Oscillograph was ingeniously employed in these researches.

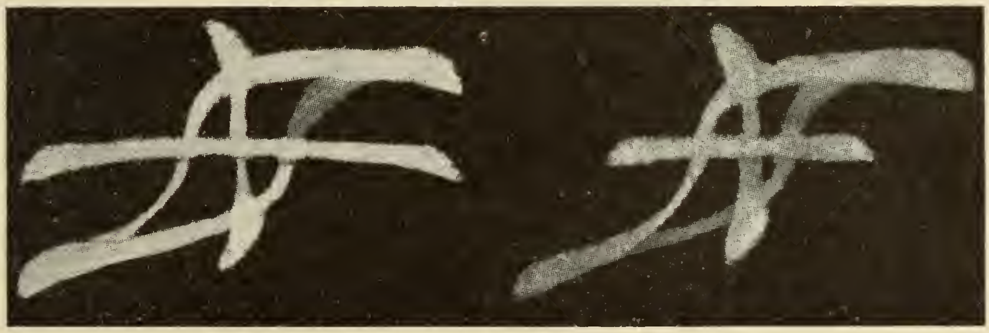
O. M. Corbino[24] (1903) was not only the first to photograph the hysteresis loop of iron at the higher frequencies, but he also was the first to use undamped alternating currents from the Poulsen arc in this kind of work. His test piece and oscillograph were arranged after the method of Ångstrom (*Physical Review*, vol. 10, pp. 74–82, Feb., 1900). The iron core tested was composed of wires 0.25 mm. in diameter. Photographs of hysteresis loops at frequencies from 4 to 20,000 cycles per second were shown in the original publication, the loops at the lower frequencies being slim and showing high saturation, while those at the higher frequencies were much thickened and distorted by the influence of eddy currents. Two of these loops are reproduced here as Fig. 2 and Fig. 3, respectively. Fig. 2 was made at 4 cycles per second and Fig. 3, which has a much larger area, was made at 11,000 cycles per second. The work of Schidlof[25] (1905) on the B-H loop, for the purposes of this discussion need merely be mentioned since the highest frequency attained was 1250 cycles per second. Battelli and Magri[26] (1906) also used the Ångstrom method with their Braun Tube but the source of current was a 10,000 cycle alternator built after the designs of

FIGS. 2 AND 3.



Hysteresis loops of iron wires at 4 cycles per second and at 11,000 cycles per second respectively. (Corbino.)

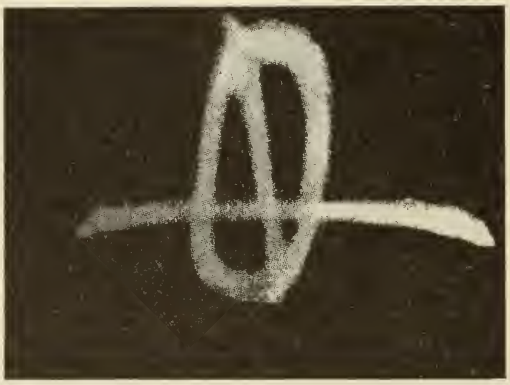
FIGS. 4 AND 5.



Hysteresis loops of fine steel wires at 50 cycles per second and at 10,000 cycles per second respectively. (Battelli and Magri.)

Lamme. (*Trans. A. I. E. E.,* vol. xxiii, p. 417, 1904). One test piece was of steel wires 0.005 cm. in diameter, two were of iron wires 0.01 and 0.03 cm. in diameter, respectively, and one was a solid bar of steel. Photographs of the hysteresis loops shown by these samples at 50 cycles per second and at 10,000 cycles per second form part of the report of these authors. In the case of the steel wires and the 0.01 cm. iron wires the low frequency loop (Fig. 4), and the high frequency loop (Fig. 5) are practically identical except that the former has a slightly larger area. Both are thin and show high saturation. The 50 cycle loops of the 0.03 cm. iron wires and the steel bar are similar to those of the other two test pieces, but at 10,000 cycles the iron wires have a thick stubby loop and the loop of the steel bar (Fig. 6) is an ellipse with major axis nearly coinciding with the B axis. The distortion of the last mentioned loops, which distortion may be seen from Fig. 6 to be large, is ascribed to eddy currents in the test piece. A publication by Corbino[27] in 1907 compared his observation in 1903, that the area of the hysteresis loop increased slightly at higher frequencies, with the observation of Battelli and Magri which indicated the opposite condition, and concluded that the difference must have been due to difference in the test pieces.

FIG. 6.



Hysteresis loop of solid steel bar at 10,000 cycles per second. (Battelli and Magri.)

THEORETICAL CONSIDERATIONS.

The opinion that experiment had indicated the possibility of explaining the action of iron under high frequency magnetic excitation along purely conventional lines and without ascribing any inherent sluggishness to the elementary magnetic units of the iron, is registered by the subject matter of certain books issued shortly after 1900.

J. J. Thomson[28] investigated mathematically the transmission of magnetic impulses along a wire. J. Zenneck[29] in a résumé of the work on this subject indicates that a solid iron bar of one centimeter radius acts, for high frequency magnetization, like a tube in the sense that practically all the magnetic field is in a thin surface layer. This phenomenon is called magnetic skin effect. He includes a discussion of theory and experiment in relation to this behavior of metal cylinders.

The attitude of some advanced thinkers at this time (1909) is put very clearly and concisely by Steinmetz,[30] who says: "To fully utilize the magnetic permeability of the iron it therefore has to be laminated so as to give at the impressed frequency practically uniform magnetic induction throughout its section, that is, negligible eddy currents. This, however, is no longer the case even with the thinnest possible laminations at extremely high frequencies as oscillating currents, lighting discharges, etc., and under these conditions the magnetic flux distribution in the iron is not uniform but the magnetic flux density B decreases rapidly and lags in phase with increasing depth below the surface of the lamination, so that ultimately hardly any flux exists in the inside of the laminations, but practically only a surface layer carries magnetic flux. The apparent permeability of the iron decreases at very high frequency and this has led to the opinion that at very high frequencies iron cannot follow a magnetic cycle. There is, however, no evidence of such a 'viscous hysteresis,' but it is probable that iron follows magnetically even at the highest frequencies, traversing practically the same hysteresis cycle irrespective of the frequency of the true M. M. F., that is, if the resultant of the impressed M. M. F. and the M. M. F. of the eddy currents in the iron is considered. Since with increasing frequency at constant impressed M. M. F. the resultant M. M. F. decreases, due to the increase of the demagnetizing eddy currents this simulates the effect of a viscous hysteresis." A table is then worked out showing the "penetration" in various materials at various frequencies. "Penetration" is defined as the thickness of a surface layer of flux which has the same density throughout as the real flux has at the surface and which has the same total flux as actually exists in the material. The table is here reproduced as Table I. By mathematical derivation it is

TABLE I.

Penetration in Centimeters.

Material	μ	Specific resistance	Frequency, cycles per second				
			25	60	1000	10,000	10^6
Soft iron.............	1,000	10^5	0.0714	0.046	0.0113	0.0036	0.00036
Cast iron............	200	10^4	0.504	0.325	0.080	0.0252	0.0025
Copper..............	1	6×10^5	0.922	0.595	0.144	0.0461	0.0045
Resistance alloys.....	1	10^4	7.14	4.60	1.13	0.357	0.036

shown, as had been shown by some previous writers, that the speed of propagation of a magnetic impulse into solid iron "is inversely proportional to the square root of the electric conductivity and of the magnetic permeability, but directly proportional to the square root of the frequency. This gives a curious instance of a speed which increases with frequency." It is further shown by calculation that with reference to an iron plate only 0.036 cm. thick, when the real permeability μ is 1000 and the specific resistance 10^5 microhms per centimeter cube, the apparent permeability $\mu' = \frac{B_{av.}}{H}$ will have values at various frequencies as follows:

Frequency.	Permeability
Very slow	1000
10,000 cycles per second	198
1,000,000 cycles per second	18.8
100 x 10^6 cycles per second	1.98
392 x 10^6 cycles per second	1.0

At still higher frequencies it is stated that the presence of the iron will actually reduce the magnetic flux.

In the experimental field again, Drysdale[31] (1911) in some investigations on longitudinal magnetic waves along an iron bar found that the bar acted like an electric cable in which there is no capacity. According to his conclusions the reluctance of the bar corresponds to resistance in a cable and the eddy current coefficient of the bar corresponds to the inductance of a cable.

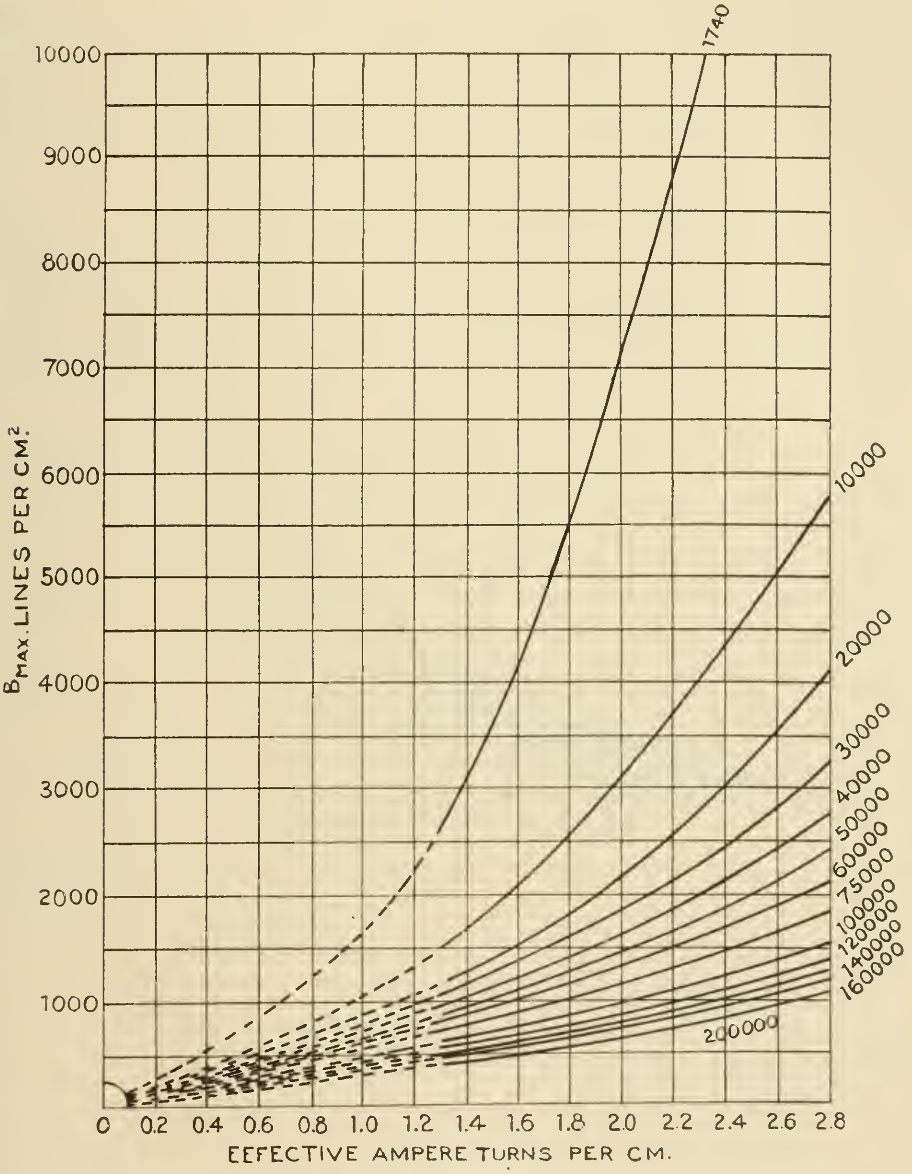
CORROBORATIVE EXPERIMENTS.

Efforts to determine whether "iron follows magnetically even at the highest frequencies traversing practically the same hysteresis cycle irrespective of the frequency of the true M. M. F." (Steinmetz) were made by Fassbender and Hupka[32] in 1913. Using an arrangement of the Braun Tube and the tuned secondary circuit of a Poulsen arc they obtained on the screen, curves whose coördinates were, respectively, the sinusoidal magneto-motive force in the field of the magnetizing coil around the iron sample, and the voltage at the terminals of the magnetizing coil. The voltage variation was separated by the usual procedure (see H. J. Ryan, *Trans. A. I. E. E.*, vol. 22, p. 545, 1903) and reduced to rectangular coördinates of time and voltage. This wave, integrated by a graphical method (see Bedell & Bown, *Electric Journal*, vol. 12, p. 23, 1915), yielded the flux cycle which, combined in its proper phase relation with the sinusoidal M. M. F. on B-H coördinates, gave the hysteresis loop followed by the sample. Reproductions of voltage and flux waves and of photographs of the original figures were shown in the publication. The three samples of iron laminations 0.03 mm., 0.06 mm., and 0.10 mm. thick, respectively, were submitted by the Telefunken Company. It is stated that the field strength in the iron was 30 gausses. Tests were made at frequencies of 30,700, 56,600, 89,700 and 132,000 cycles per second. Some of the conclusions reached may be freely translated thus: "The photographs and also the curves for a given iron sample show, for the different frequencies little relative variation, although the set of curves for one test piece is quite different from that for another test piece. The thinnest of the test plates (0.03 mm.) shows on the whole the most typical iron curve. In the test of the 0.06 mm. thickness plates the figure shown by the oscillograph, on account of the magnetic skin effect degenerates into an ellipse. The sheet of 0.10 mm. thickness exhibits a gradation between both the other test plates. It is surprising that in the thickest plates the skin effect apparently exercises a smaller influence than in the 0.06 mm. plate." To show that this was not an experimental error the work was repeated with variations of conditions without change in the results. The authors believe that with such thin laminations the rolling process may have a large effect on the amount of active material in the plates. The surface layers of oxide, etc., form a considerable part of the total thickness and these surface layers are upon examination shown to be quite variable. The results of the experiments of Fassbender and Hupka even more definitely than those of some previous researches substantiate the view that when magnetic skin effect is greatly reduced by the use of iron laminations having large surface as compared with their cross section, the permeability and the character of the hysteresis loop are but little affected by a wide range of frequency variation. A few later experiments which had some bearing on this conclusion will be briefly mentioned.

Rohmann[33] in 1914 published some interesting photographs of Braun Oscillograph records of magnetic cycles in steel and iron samples magnetized by damped oscillating currents at about 3×10^5 cycles per second. Jonaust[34] (1910) and Bonazzi[35] (1911) worked with undamped and damped oscillations, respectively. Marchant[36] (1913) using leyden jar discharges at 5000 to 100,000 cycles per second through coils with iron cores, photographed the spark discharge in a revolving mirror and obtained results which show the same general characteristics as those of other workers. It is stated that in calculating the results skin effect was taken into account. In the conclusions the author remarks, "The curve connecting μ the 'effective' permeability $\left(= \frac{Bav.}{H} \right)$ with H the magnetizing force agrees within the limits of experimental error with that obtained on the assumption that the permeability of the iron is the same as it is under a steady magnetizing force."

The matter of the behavior of μ having been fairly well settled, more attention was focused upon the practical question of core losses. By means of his 200,000 cycle alternator Alexanderson,[37] in 1911, was able to get such steady conditions for his measurements as to make simpler the collection of a large amount of accurate data. The sample was an iron ring 5.1 cm. in diameter made up of ten turns of a soft iron strip 0.0076 cm. thick and 1.9 cm. wide. The layers of the strip were separated by thin paper and the winding was made of silk covered copper wire with two wires in parallel and twenty turns in series. "The skin effect measurements consisted in determining the apparent permeability of the iron at various frequencies (40,000 to 200,000 cycles per second), and flux densities by observing the volts and ampères at the terminals of the sample coil." The core losses were measured by a substitution method. Although the experiments were made largely to determine how the iron could be used in high frequency apparatus, the results were also interpreted in the light of theory. The paper says, "As a conclusion from these tests it may be stated that the opinion held quite extensively that iron does not respond to high frequencies is entirely without foundation. The iron not only responds but seems to have the same permeability at 200,000 cycles per second as at

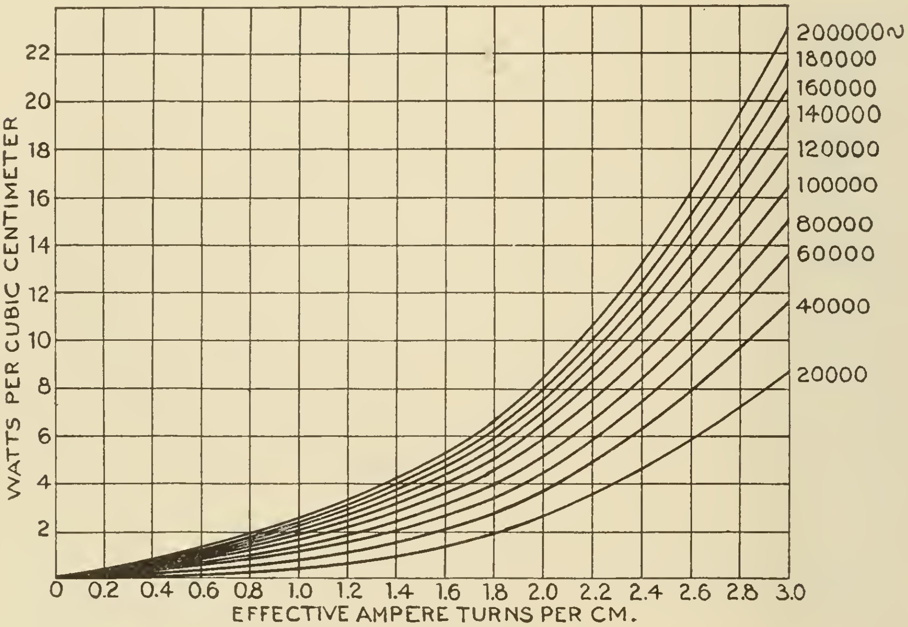
FIG. 7.



Alternating current saturation curves of very thin sheet iron. (Alexanderson.)

60 cycles per second. The apparent permeability of the iron in the sample which was tested is only about one-tenth as great at the high as at the low frequencies, but the decrease of the apparent permeability is substantially in agreement with the change that would be expected from purely theoretical considerations due to the skin effect, which indicates that the actual permeability has remained unchanged." Calculation by Steinmetz's formula shows the penetration at 200,000 cycles per second should be 0.00056 cm., while calculation from the data shows it to be 0.0003 cm. "The discrepancy between the measured and calculated values of the penetration is probably due to the fact that the coil has not a completely closed magnetic circuit, but depends upon leakage from turn to turn of the laminations, whereby an additional skin effect is created." The iron sheets used by Alexanderson are about as thin as can be manufactured nowadays, and therefore his results are particularly interesting because they show what can be done with iron in high frequency fields when a proper method is pursued. The saturation curves and curves of core losses are copied here as Fig. 7 and Fig. 8, respectively.

FIG. 8.



Core losses in very thin sheet iron as a function of frequency and field intensity. (Alexanderson.)

In the discussion of Alexanderson's paper, Silsbee[38] reported some experiments made by him in 1910–11. Toroidal rings 8 cm. in diameter and 0.2 sq. m. cross section were made of insulated iron wires from 0.050 mm. to 0.228 mm. in diameter. These were wound with magnetizing coils through which passed 350,000 cycle current from a Poulsen arc. Magnetizing current and voltage were recorded. The calculations included skin effect, hysteresis and eddy currents. The results showed that the real permeability of the iron after these factors had been allowed for was practically the same at 350,000 cycles as at low frequencies, "at least over the range of H used." This range is not stated. "The observed values of the energy component were uniformly low which suggested that possibly the hysteresis loss per cycle might be less at higher frequencies when the molecules are subjected to such rapid agitation."

McLachlan[39] (1915) made core loss tests on 0.33 mm. plates of two special steels known as Stalloy and Lohys, and reported data as in Table II. A strip of the steel placed in the magnetizing coil became red hot in three seconds unless surrounded by water. These figures show the enormous values to which the core losses may rise under extreme conditions. Tests (1916) of apparent permeability and core losses at frequencies up to 10^6 cycles per second resulted in data consistent with those of previous work.

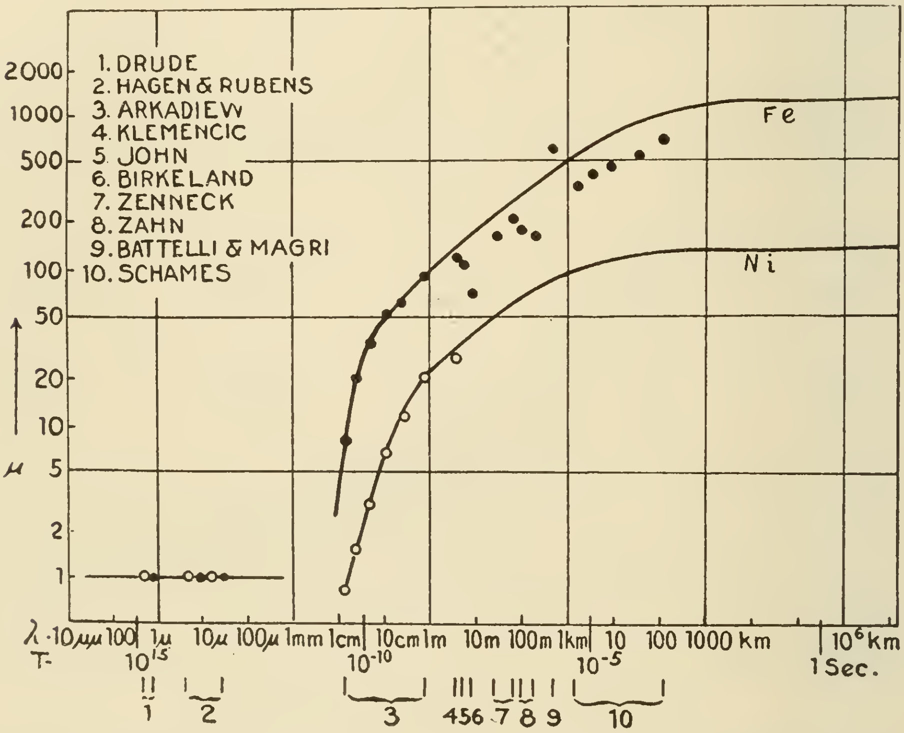
TABLE II.

B max. apparent	H max. apparent	μ apparent	Watts per kilogram	Frequency cy. per sec.
3500	21	170	48,000	1.9×10^5
4300	17	250	44,000	1.7×10^5
3200	25	130	57,000	2.1×10^5

BEHAVIOR AT EXTREME FREQUENCIES.

While experiment has shown that the true permeability of iron is unaffected by frequency through a range from zero to perhaps 10^6 cycles per second, yet it must be noticed that this cannot be true at much higher frequencies, for at the frequency of light and heat waves the permeability of all metals is unity. What happens in the region between these widely separated conditions was investigated by Arkadief[40] who writes, "In the winter of 1907–08 I busied myself with measurements by different methods of the reflecting power of metallic wires for electric waves and I have found that the difference in the relations between magnetic and non-magnetic wires is much larger for the longer waves (30 cm.) than for the shorter ones (3 cm.). This, one can only explain by the decrease of the permeability with wave length. In an earlier theoretical and experimental research I have given mathematical formulæ for the calculation of the absorption coefficients for undamped electric waves in two parallel wires and I have found that the measured values for non-magnetic wires are in good agreement with the theoretical values, which makes possible the calculation of the permeability of magnetic wires from the values of their measured absorption coefficient."

FIG. 9.



Compilation of data on high frequency permeability. (Arkadief.)

These earlier investigations [41] of Arkadief consisted in measurement by means of a delicate thermo-element of the attenuation or absorption of electric waves propagated along two wires. The energy of the waves is found to fall off according to an exponantial relation. Calculations based on a theoretical formula showed that for non-magnetic materials the observed and calculated values of the absorption coefficient differed by less than the possible experimental error, which was small. Data from observations on similar magnetic wires were then placed in the formulæ and, working backward, the value of μ was deduced. For soft Swedish iron wires 0.02 mm. in diameter in very weak fields the values were:

Wave length in cm.	Permeability. μ
72.7	80.
23.8	58.
10.63	51.
4.82	33.5
2.31	14.7
1.31	4.5

The extrapolation of these data showed that μ became unity for iron with waves a few millimeters in length. A curve is drawn [40] (reproduced here as Fig. 9) which exhibits Arkadief's results as connecting smoothly the results of Rubens in the region of heat waves with those of other experimenters at wave lengths near 1000 meters. Further experiments by Arkadief [42] in which the energy of short waves reflected from a lattice of fine wires of magnetic material was measured by a delicate thermo-element, confirmed the accuracy of the previous investigations of that author.

The question of what happens to μ, or in fact of what meaning the ratio B/H has in the region of wave length which lies about the natural radiation wave lengths of atoms and molecules, is a question which is too undecided to even conjecture upon here. The matter obviously involves theories of the magnetic structure of materials which are far from settled. Arkadief [43] has made some mathematical investigations of what is to be expected in this region.

SUMMARY.

Not many years ago it was quite generally believed that iron was unable to follow rapid magnetic changes. Experiments which showed an apparent decrease in the permeability of the iron with an increase in the frequency of the magnetic cycle furnished a basis for a theory that iron was magnetically sluggish. Further and more accurate experiments proved, however, that the effects which had previously been ascribed to a peculiarity of the material were in reality caused by eddy currents in the sample. Theoretical calculations were made which demonstrated that eddy currents in an iron test piece increased as the square of the frequency and that for even the lower frequencies it was necessary to use quite thin laminations in magnetic circuits in order to eliminate deleterious effects. Furthermore, it was found that due to eddy currents and the magnetic properties of iron, the magnetization in high frequency fields was confined to a thin surface layer of the piece. This "Magnetic Skin Effect" reduced the cross section of the iron which was magnetically active even though the laminations were extremely thin. Careful experimental measurements compared with theoretical calculations proved that the real permeability of iron remained unchanged at frequencies up to about 10^6 and that previous results had been in serious error due to neglect of the factors mentioned. This fact having been established, efforts were made to see what practical use could be made of iron in high frequency work and to that end some extensive experimental investigations of the saturation curves and core losses were made upon specimens laminated as thinly as was commercially practicable. The resulting data have furnished a basis for design.

It is a demonstrated fact that the permeability of all metals is unity for the magnetic cycles imposed upon them by heat and light waves. In the region between frequencies of about 10^6, where the true permeability of iron is practically the same as at zero frequency, and frequencies of about 10^{10} where the true permeability of iron approaches unity, the experimental values of μ decrease smoothly with the frequency. What happens to μ in the range of frequencies between the longest heat waves and the shortest Hertzian waves which have yet been made is a question which has many interesting features but which has not yet yielded to the experimenter.

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Nickel and Tin. C. S. TRENCH. (*Brass World*, vol. 12, No. 11, November, 1916.)—Nickel and tin are the only metals we seem unable to find among our mineral resources. There is no substitute for tin. Unlike other metals, the price has no effect on consumption. If tin were at 15 cents we would perhaps put more on our tin plates and make better solder and babbitt metal. If it were one dollar per pound we would still have to use it for nearly every use for which it is employed. Tin is one of the weakest points in America's self-sufficiency as a nation. The effect of being cut off from tin would create sanitary troubles that would prove very serious. In the opinion of the writer, tin at present prices is on a safe basis and after the war much higher prices are to be expected. Tin is the only metal selling to-day at less than the average price of two years before the war, the price being 10 per cent. lower, while the prices of other metals are 52 to 180 per cent. higher.

Research Fellowships in the Engineering Experiment Station of the University of Illinois.—The value and the need of organized industrial research, carried on upon a scale in keeping with our very large natural resources, are becoming more and more appreciated and recognized. Private laboratories of industrial research have already demonstrated their utility in yielding handsome returns to their promoters and notable contributions to the advancement of science. Only too few laboratories of that type are maintained by educational establishments, and, at this hour of a general awakening to the importance of the movement, the announcement that nine vacancies among the Research Fellowships in the Engineering Experiment Station of the University of Illinois will be available at the close of the current academic year is of most timely interest.

The Engineering Experiment Station, an organization within the College of Engineering, was established in 1903 for the purpose of carrying on investigations in the various branches of engineering, and for the study of problems of importance to engineers and to the manufacturing and industrial interests of the State. The work of the station is closely related to that of the College of Engineering, and the heads of departments in the college constitute the administrative station staff. Investigations are carried on by members of the station staff and other members of the instructional staff of the College of Engineering by special investigators employed by the station, and by the research fellows. Nominations to these fellowships, accompanied by assignments to special departments of the Engineering Experiment Station, are made from applications received by the Director of the Station each year not later than the first day of February.

Additional information may be obtained by addressing the Director, Engineering Experiment Station, University of Illinois, Urbana, Illinois.

THE LUMINOUS EFFICIENCY OF THE RADIATION FROM THE ELECTRIC ARC.

BY

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Member of the Institute.

In a previous work[1] a method for obtaining the luminous efficiency of the radiation of a light source was perfected and values for the luminous efficiency of the radiation from various common light sources both gas and electric were given.

It was found that the method employed in the investigation of ordinary light sources was quite unsatisfactory for investigating the arcs, for the variations that are continually present in the arc would necessitate the taking of a very large number of observations.

There are obviously several methods which may be used to avoid this difficulty. One of the first to suggest itself was to have some means of recording the ratio of the two quantities required (viz., the total radiation and the radiation through the "luminosity" screen). This might be accomplished with a bolometer arrangement in which the material as a platinum strip of one arm of a Wheatstone's bridge is exposed to the whole radiation, while that in the other is exposed to the same radiation after passing through the luminosity screen. This method had already been suggested by Ives.[2]

A second method would be to record a large number of observations photographically, and take a mean directly from the curve such as a photographic recording device would give.

A third method would be to have some integrating means whereby the average rate of energy-radiation over an extended time could be obtained.

The photo-electric cell perhaps could be adapted to this end for measuring the radiation through the luminosity screen, or possibly some photo-chemical means. For an integrating total radiation meter, however, no simple means is at hand.

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[1] *Physical Review*, n. s. vol. v, No. 3, p. 189, March, 1915.

[2] *Electrical World*, June 18, 1912.

A Nichol's or a Crooke's radiometer might possibly be made to operate some mechanical or electrical device to this end. Or the radiomicrometer might perhaps be developed into an integrating radiometer.

There is a fourth method, however, which is simple and direct. Its disadvantage is that it necessitates duplication of apparatus.

If two thermopiles are at hand, two sensitive galvanometers, and two observers, it is obviously simple to record approximately simultaneous conditions of the light source as to its radiation with and without the luminosity screen.

This method is the one employed in the present investigation. Two galvanometers were employed, though one galvanometer may be dispensed with as will be noticed later. The one galvanometer will be referred to as Galvanometer I, and the other as Galvanometer II. Galvanometer I was a high sensitivity Leeds and Northrup's galvanometer, whose description as given by the makers is as follows: sensibility 33 mm. for 1 microvolt across the terminals; resistance 12.5 ohms, critically damping resistance 32 ohms, period 7.5 seconds. Galvanometer II was constructed by the author some time previously, and modified to suit the present purpose. Its sensibility was obtained by comparing with Galvanometer I. When the two galvanometers were connected in series with a resistance, and an ordinary dry cell, so that the same current was flowing through the galvanometers, Galvanometer II gave deflections 2.6 times as large as Galvanometer I. When the same potential difference was put across the terminals of each galvanometer, separately, Galvanometer II gave deflections 3.6 times as large as Galvanometer I.

For this latter comparison a dry cell with a suitable resistance in series was connected to the terminals of each galvanometer in succession.

The resistance of Galvanometer II was approximately 26 ohms; period 7 seconds. This comparison does not give an adequate estimate of the relative merits of the galvanometers perhaps, for it will be shown below that each galvanometer had its own superior qualities.

The two thermopiles will be denoted as Thermopile I and Thermopile II.

Thermopile I was taken from the infra-red spectrometer manufactured by the Adam Hilger Co., London. It consists of ten Bi-Ag junctions in series, and had a total resistance of about 3 ohms. Its receiving surface was 2 mm. × 10 mm.

Thermopile II was constructed by Dr. W. W. Coblentz. It consisted of twenty junctions in series of bismuth and silver with a total resistance of about 12 ohms. Its receiving surface was 3 × 22 mm. approximately.

With the thermopile and galvanometers having such different resistances there was of course some choice as to the combinations of thermocouple and galvanometer to be used, and those giving greatest sensibility for the work at hand could be selected.

To show the difference in the behavior of the galvanometers when connected with first, Thermopile I, and secondly with Thermopile II, the following table is given:

	Relative sensibility	Time to reach maxim. deflections
Galv. I with Thermopile I	2.8	13.5 sec.
Galv. I with Thermopile II	3.5	8.0 sec.
Galv. II with Thermopile I	1.8	23.0 sec.
Galv. II with Thermopile II	4.1	20.0 sec.

These deflections were obtained when the radiation from a tungsten filament lamp (40 watts) operated at 112 volts was allowed to fall upon the thermopiles. The lamp was 23 cm. away; the scale about 1 meter distant.

It is seen here that Galvanometer I gives greater deflections with Thermopile II than with Thermopile I, and Galvanometer II gives also the greater deflections with Thermopile II. For brevity we shall designate the latter combination as Radiometer II; and the Galvanometer I together with the Thermocouple I as Radiometer I. These differences in sensibility are such as may be expected from a consideration of the resistances of the galvanometer and of the thermopiles, yet it shows the importance of choosing the proper galvanometer for a given thermopile and the proper thermopile for a given galvanometer.

Radiometer II was 40.6 per cent. more sensitive than Radiometer I. The Radiometer II was the most sensitive combination of thermocouple and galvanometer available, and was employed throughout the test to measure the radiation after passing through the luminosity screen; while Radiometer I was employed to measure the radiation directly.

The deflections actually obtained with the former for ordinary illuminants when the luminosity screen was interposed were, of course, very much smaller than those obtained with the latter exposed to the full radiation. To make the deflections comparable the slit in front of the Thermocouple I was closed, so that a very small part of its total receiving surface was exposed.

The two radiometers as used were tested for linearity of deflections by exposing to the radiation from a tungsten lamp which was placed at various distances. It was found that up to quite large values, 20 to 30 cm., the deflections were proportional to the intensity of the radiation to within one per cent.

The Radiometer I was calibrated in terms of Radiometer II, for it is to be noted that the Radiometer I was employed merely to indicate what the Radiometer II would have indicated when the luminosity screen was not before it. To reduce deflections given by Radiometer I to those given by Radiometer II they are to be multiplied by 34.4. Corrections for optical path and for the absorption by the cell were made later and are not included in the factor 34.4.

The luminosity screen used was the combination specified by Ives [3] and described in detail by Ives and Kingsbury [4] in connection with a method of physical photometry. It consists of a 1 cm. thick tank containing a mixture of copper chloride, potassium chromate and cobalt ammonia sulphate, together with a protective tank of water 2.5 cm. thick. This combination has been exhaustively tested by them as to its agreement with the visual luminosity curve, and also as to the adequacy of the water layer to block all infra-red radiation transmitted by the colored elements in the 1 cm. tank.[5] The cell allowed 57 per cent. of energy to pass at the wave length of its maximum transparency.

The thermopiles, placed side by side, were enclosed in a large tin box packed with cotton and carefully shielded from all extraneous radiation by many screens of heavy cardboard stationed at short intervals between the light source and the radiometers. The screen next to the source was a photometric screen made of sheet iron and about 16 inches by 24 inches and one-sixteenth of an inch thick. The shutter consisted of a wooden frame covered on one side with bright sheet iron (commonly called "tin") and on the other with blackened cardboard. The air space was approximately three-eighths of an inch. This double screen had been found very satisfactory in the earlier work.

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[3] Trans. Ill. Eng. Soc., x, 4, p. 315, June, 1915.

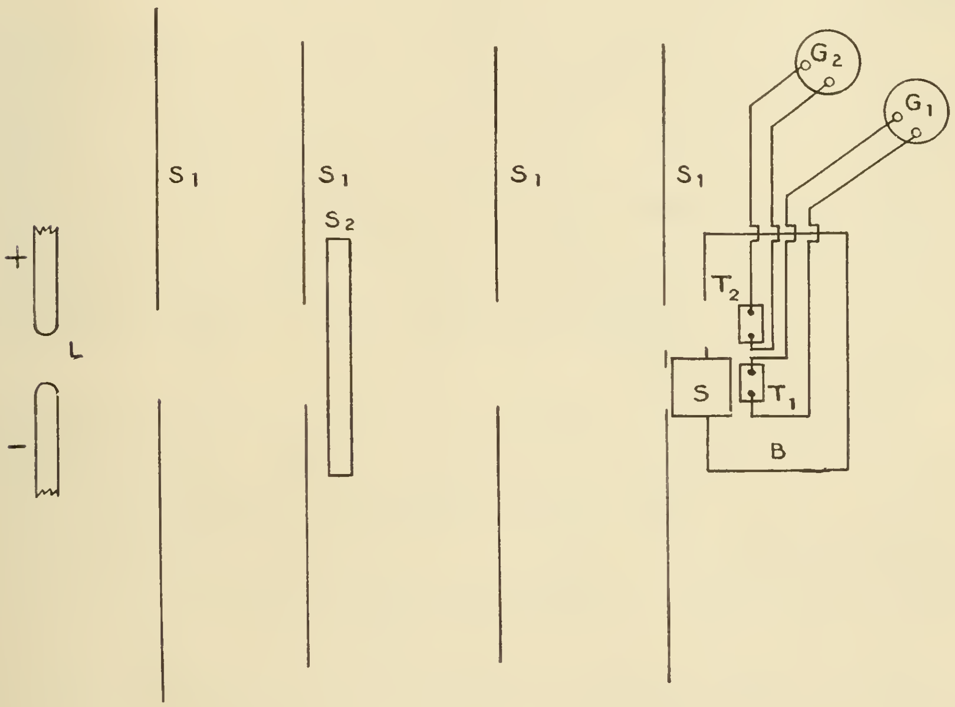
[4] *Physical Review*, Nov., 1915, p. 319.

[5] "The Luminous Efficiency of the Carbon Incandescent Lamp and the Mechanical Equivalent of Light," *Physical Review*, vol. 8, p. 254, 1916.

Fig. 1 is a schema of the disposition of the apparatus.

(L) is the light source studied; (S_1) screens; (S_2) double walled shutter; (B) sheet iron box enclosing thermocouples (T_1) and (T_2); (S) cell containing the luminosity solution.

FIG. 1



Diagrammatic sketch of the set-up of apparatus.

The thermocouple (T_1), together with the galvanometer (G_1), constituted Radiometer I and the Thermocouple (T_2) with galvanometer (G_2) constituted Radiometer II.

The thermocouples were both mounted in heavy brass enclosures as usually done by makers of these instruments.

Long portions of the leads from the thermocouples to the galvanometers were retained within the walls of the enclosure B which was loosely filled with cotton.

The electrodes of all the arcs investigated were held vertical in a pair of carbon holders made for the "Excello" arc lamp. Two vertical iron rods were adapted as slides for the holders so that the electrodes could be set at any desired distance apart. The lower electrode holder was held in a clamp. All electrodes were held in these holders and when necessary the diameters of the ends were turned down in the lathe until the holders could receive them. The apertures in the screens were such that a portion of the electrodes to either side of the arc could radiate on to the thermopiles. The holders, however, were not always in a position to do so. The arc was made by lowering the upper electrode until it made contact with the lower.

All measurements were made in a horizontal direction, and at a distance of from 1 to 1.25 meters from the arc.

Emphasis must be laid upon the fact that the values here given refer to a particular direction and to the arc in most cases with little or no accessories. Any variations in the latter will of course give different values by varying the relative amounts of energy dissipated by the source through the channels of convection, conduction and radiation. This was pointed out in the earlier paper referred to above. This must be kept in mind when the figures given here are compared with other constants and properties of the light sources studied.

The electrodes were obtained at the time the work referred to above was in progress (in the spring of 1914). These electrodes had been kept in their original packing in the basement of the laboratory where the temperature and moisture conditions were somewhat variable. On several of the carbons were noticed light grayish specks which could be quite easily brushed off.

The results obtained are in most part shown in the diagrams of Fig. 2. These are not to be taken as curves depicting the behavior of the various arcs. The points plotted in most cases represent isolated, widely separated observations, but connected by straight lines to avoid confusion. One may get a rough comparison of the various arcs as to the efficiency of their respective radiation by a glance at the points indicated in the figure.

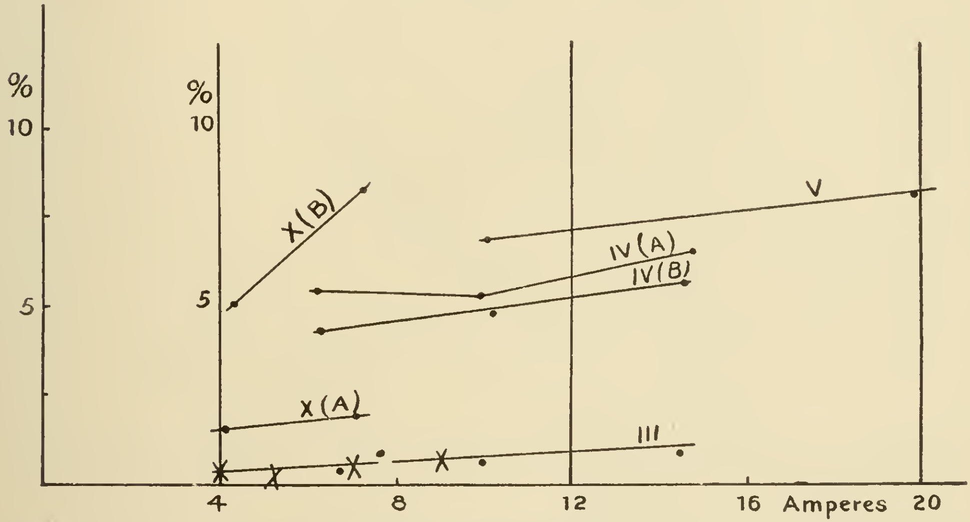
Eleven arcs in all were studied. The data for the Arcs I and II have been omitted. A different absorption cell was employed, whose maximum transmission had not been determined.

Electrodes in Arcs I and II were solid carbon and the small luminous arc carbons. Data for both of these types were again obtained with the luminosity solution finally employed, and are given under Arcs III and IV. Only in one case were determinations made on the arc with its complete fixtures as it is obtained on the market. This was the so-called "Excello" lamp. The electrodes used in this instance were the yellow flame carbon 8 and 9 mm. × 600 mm. It was operated under normal conditions, *i.e.*, on 10 ampères and 55 volts.

A cooling curve was taken for this lamp so that correction could be made for the radiation from the inner and outer globes, and such portion of the metal fixtures as may have been contributing.

In all cases at least two different sets of electrodes for every condition were used. From three to six observations were made for every condition for every pair of electrodes.

FIG. 2



Curves showing the relationship between luminous efficiency of the radiation from and the current through the arc.

The values given in the table below and plotted in the curves of Figs. 2, 3 and 4 are the mean values of these observations. A detailed description is given below of the electrodes used and of the conditions under which they are normally used. Roman numerals refer to the same arc as the curves marked with the same numerals in the Figs. 2, 3, and 4.

III Ordinary D. C. 110 volts solid carbon ½ inch × 12 inches vertical trim, 80 volts at arc; 5 ampères for use in enclosed arc lamp. This type of carbon is being superseded by the flame arc carbons.

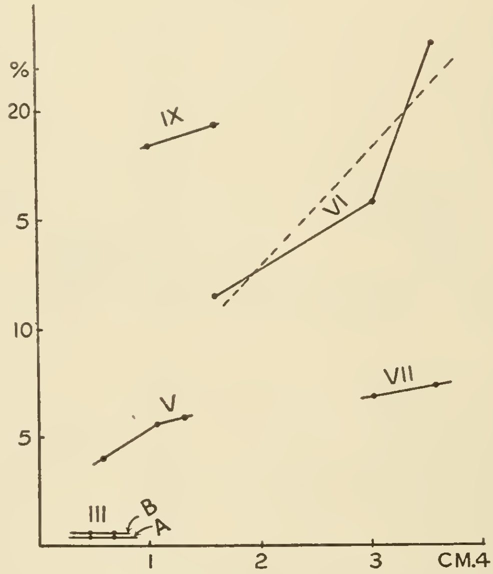
IV. Luminous arc, Columbia, silver tip, yellow flame, cored carbons, negative electrode 9 inches × 600 mm., positive electrode 10 mm. × 600 mm.

V A. C. Luminous arc, yellow flame carbons cored, 8 × 600 mm. Carbons IV and V are designed for the incline trimmed lamp two in series on 110 volts; 45 volts at arc. These carbons have the flame material in the core and are for use in a semi-enclosed lamp, such as the "Excello."

VI A. C. ⅞ inch × 14 inches; 441 H. Yellow flame Homogeneous.

VII A. C. ⅞ inch × 14 inches; 452 H. White flame Homogeneous.

FIG. 3



Curves showing the relationship between the luminous efficiency of the radiation from the arc and the length of the arc.

VIII D. C. ⅞ inch × 14 inches; 452 H. White flame Homogeneous.

IX D. C. ⅞ inch × 14 inches; 441 H. Yellow flame Homogeneous.

Carbons in Arcs VI, VII, VIII and IX have the flame material directly embodied in the body of the carbon. They are designed for operation in vertical trim enclosed flame arc lamps such as the G. E. Co. form W. lamp.

The No. 441 H. yellow flame carbons are adapted for D. C. service at 7 ampères, 65 volts at arc on 110 volt line. Tests were also made with A. C. at 10 ampères, and 65 volts on the suggestion of Mr. R. B. Chillas.

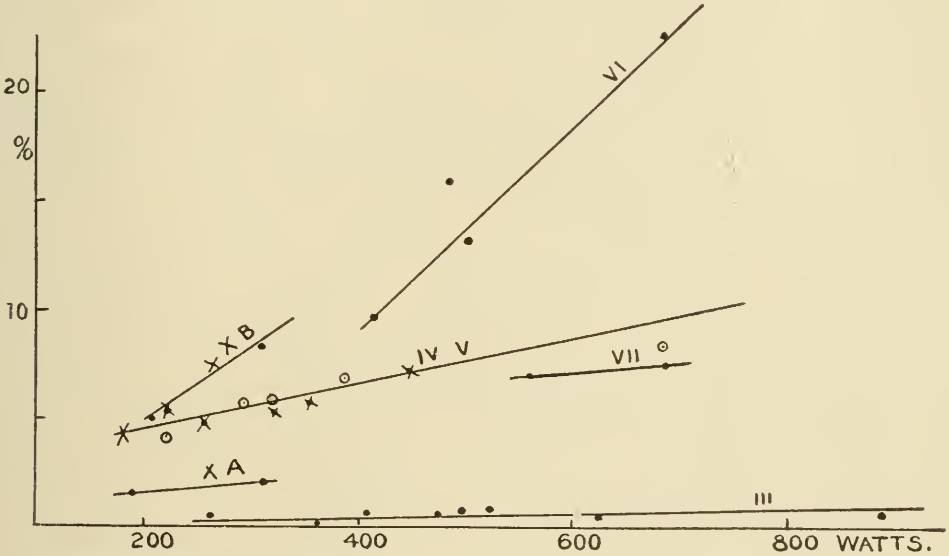
The No. 452 H. White flame Carbons are for A. C. service at 10 ampères or D. C. at 7 ampères and 65 volts.

The solid flame carbons are for enclosed arc service. When burned with full access of air an insulating slag forms, which at times gave a little trouble during the work, and had to be removed.

X Standard magnetite carbons are used on D. C; 4 to 7 ampères with the electrode as cathode: the anode may be a block of copper.

XI "Excello" lamp equipped with luminous carbons described under IV.

FIG. 4



Curves showing the relationship between the luminous efficiency of the radiation from and the rate of energy consumption by the arc.

The lamp was operated on 110 volts D. C. with a suitable resistance in series with it as is supplied with the lamp.

XII Magnesium flame three-ply wire about 0.5 mm. diameter.

A magnesium wire was at hand. This was twisted three-ply, lighted with a match and held before the radiometers. Several observations were made. It was difficult to keep the flame at the proper place, and large variations are to be found in the observations. The value given is a mean value.

The results for all the arcs are not indicated in the Figs. 2, 3, and 4. In some instances points at sufficiently great distances apart had not been obtained. Such data are only given in the table.

In Fig. 2 are indicated the points for Arcs III, IV, and V and X plotted against current.

In III the dots represent points for the Arc III when the electrodes were .68 cm. apart; while the crosses are points obtained when the electrodes were .47 cm. apart. Both sets of points fall upon the same straight line.

For the Arc IV the points on IV (A) are for a distance between the electrodes of 1.08 cm., while IV (B) are points for a length of arc 0.59 cm. The two sets of points fall to within the limits of accuracy on lines which are parallel.

For curve V (Arc V) the electrode distance was 1.33 cm. For the magnetite Arc X, curves X (A) and X (B) are both for an arc length of 0.55 cm.; in the former, however, a small brass rod ½ inch in diameter was used as anode. That such a difference in the character of the radiation may be expected is obvious; that it is as great as these few determinations of the luminous efficiency indicated cannot be averred.

It is to be noticed that a change from 0.68 to 0.47 cm. in the length of the common solid carbon arc (Arc III) does not change the luminous efficiency of its radiation. While in the case of the yellow flame Arc V an increase in the length of arc brings about an increase in the luminous efficiency of its radiation. This is also shown in Fig. 3 where the luminous efficiency is plotted against the length of arc.

For the common solid carbon Arc III, curves III A and III B Fig. 3, III A is for a current of 6.7 ampères through the arc, while III B is for 9.5 ampères. All the points lie on lines parallel to the abscissæ.

In curves V Fig. 3 it is shown that the luminous efficiency of the radiation of the yellow flame Arc V increases with the arc length. The current here was constant at 10 ampères, while the voltage varied from 22.1 to 32.0.

For VI the current was 10 ampères, while the voltage varied from 47.5 to 68.5.

In VII the current was 10 ampères, voltage 56. to 68.2.

In IX the current was 7.39 ampères, voltage 42. to 45.2.

In Fig. 4 is shown the relationship between the luminous efficiency of the radiation and the watts consumed by the arc. For all cases represented the luminous efficiency increased with the wattage.

Points for Arcs IV and V lie on the same straight line. The crosses refer to Arc IV, the circles to Arc V. Arcs IV and V are respectively the D. C. and A. C. yellow flame arcs with 8 and 9 mm. × 600 mm. electrodes.

Curves VI and VII are for the yellow and white flame arcs respectively with electrodes ⅞ inches in diameter. The great difference between these two curves and that between the slopes is perhaps exaggerated here on account of the small number of observations on only a few specimens that possibly had deteriorated slightly with age.

Curve XA, Fig. 4, refers to the magnetite arc when a small anode was used; XB to the same when a large anode was used.

It is to be noted that the A. C. yellow flame Arc VI with large electrodes ⅞ inch in diameter is more efficient than the A. C. yellow flame Arc V with small electrodes 8 and 9 mm. × 600 mm., under the conditions of the experiment, as shown by curves VI and V respectively in Fig. 4.

No. of Arc	Arc length	Amp.	Volts	Efficiency
III	0.68 cm.	6.73	69.8	.0040
	0.68 cm.	9.95	62.76	.0056
	0.68 cm.	14.41	61.51	.0097
	0.47 cm.	4.02	65.76	.0034
	0.47 cm.	6.99	57.92	.0044
	0.47 cm.	9.05	54.87	.0068
IV	1.08 cm.	6.19	35.79	.054
	1.08 cm.	9.94	32.45	.053
	1.08 cm.	14.27	30.60	.071
	0.59 cm.	6.24	29.25	.043
	0.59 cm.	10.18	25.07	.049
	0.59 cm.	14.55	24.56	.057
V	1.33 cm.	10.00	36.6	.069
	1.33 cm.	19.93	34.2	.083
	1.31 cm.	10.00	32.0	.058
	1.08 cm.	10.00	29.3	.057
	0.59 cm.	10.00	22.1	.041
VI	3.01 cm.	10.00	49.2	.158
	3.57 cm.	10.00	68.5	.225
	1.60 cm.	10.00	47.5	.115
VII	3.57 cm.	10.00	68.2	.074
	3.01 cm.	10.00	56.0	.068
VIII	1.6 cm.	7.02	46.6	.095
	1.0 cm.	7.43	35.9	.130
IX	1.0 cm.	7.40	42.0	.184
	0.6 cm.	7.38	45.2	.193

No. of Arc	Arc length	Amp.	Volts	Efficiency
X	small anode			
	0.55 cm.	7.14	43.7	.02
	0.55 cm.	4.09	46.5	.015
	large anode			
	0.55 cm.	7.29	42.7	.074
	0.55 cm.	4.35	47.4	.051
XI	without globes	8.73	59.9	.086
	with globes	8.79	50.2	.114
	Corrected for radiation from globes			
		8.79	50.2	.43
XII	Magnesium Flame			.077

This work was done during the fore part of August, 1915. The publication of it was deferred with hopes that an opportunity might arise when certain portions of the work could be repeated. Since this has not come to pass and there have been several inquiries regarding these values for the arc lamp, I deem it worth while to publish these data now. I believe that the values here given are more definite than any that may be found in the literature.

I am greatly indebted to Dr. W. R. Whitney, of the General Electric Co., for the standard magnetite electrodes; to Mr. R. B. Chillas, of the National Carbon Company, for the ordinary carbon and flaming arc electrodes used; to Mr. C. W. Jordan I am indebted for much assistance given in securing these data; to Dr. H. E. Ives for valuable suggestions and criticism.

The United Gas Improvement Company,
Physical Laboratory,
Feb. 24th, 1916.

A SHUTTER TESTING MACHINE.*

BY

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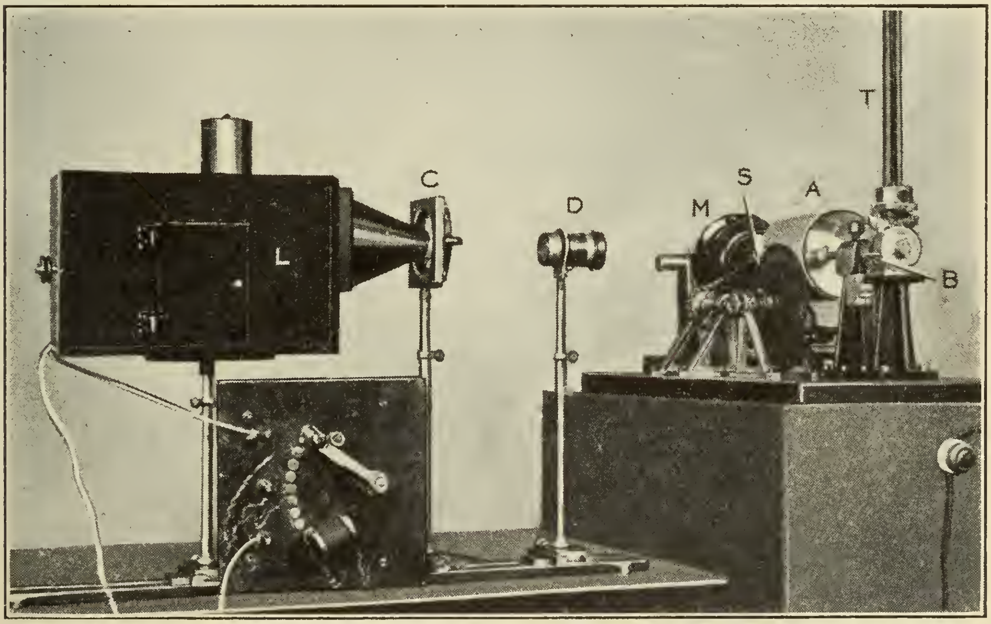
AND

F. B. GILBERT.

THE want of an instrument of precision for testing the speed and efficiency of shutters has long been felt. To date the machines of Abney and the National Physical Laboratories have been the finest, but they have failed in one or more of the requirements of precision, simplicity of operation, or durability of construction.

FIG. 1.



In the design of the one to be described these three qualities have been kept in view, and it is felt that the work has brought forth an instrument of both laboratory precision and commercial utility.

Fig. 1 shows a complete view. *A* is a revolving drum mounted on a shaft between a powerful high-speed motor *M* and a Veeder precision tachometer *T*. The speed of the drum may be varied by altering the position of the brushes but its fine regulation is achieved by the brake *B*, acting on the shaft. The accuracy of the tachometer is 1 per cent. which with the speed generally used

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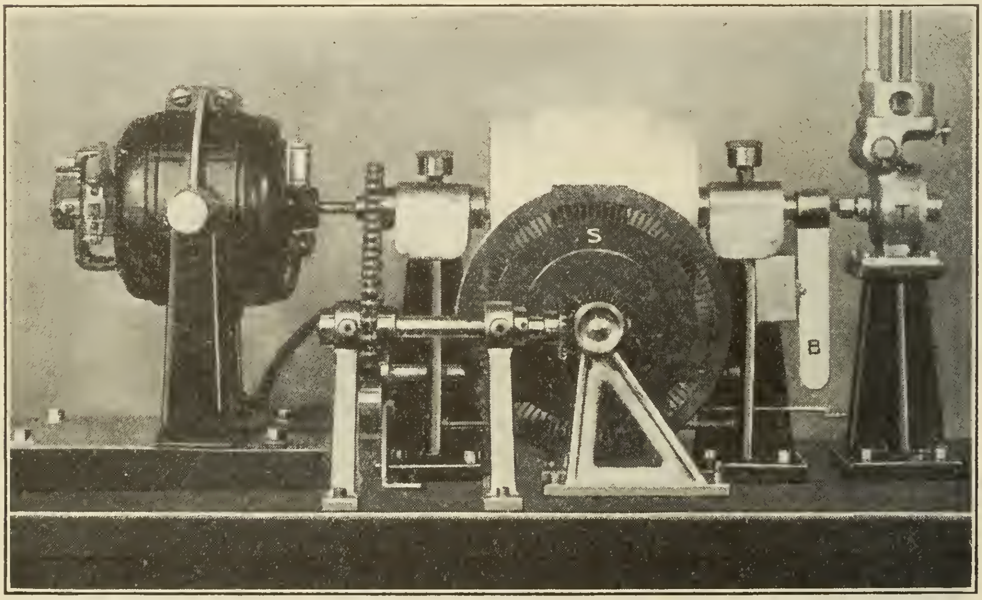
* Communication from Ansco Company's Research Laboratory.

(1250 r.p.m.) only produces an error of 1/5000 of a second in the measurement of a shutter speed of 1/50 of a second.

The shutter to be tested is held in a universal iris *C* directly in front of a narrow horizontal slit. By means of an arc and a pair of condensers in the lamp house *L* this slit is illuminated by a very powerful spot of light, while its image is brought to focus on the drum by the lens *D*. Thus on exposure there is produced on a strip of film affixed to the revolving drum a band, the length of which at a given r.p.m. determines the speed of the shutter.

To make this band self-recording and avoid the tedium of many measurements it is split up into a series of lines by the sector wheel *S* (Figs. 1 and 2) which revolves in front of the drum. The wheel contains 96 slots and by gearing to the main shaft is made to rotate at precisely the same speed as the drum; the series of lines in the image, being due to the interruptions of the sector wheel, have a definite time value. At 1250 r.p.m. each one of the lines then represents 1/2000 of a second, so that, in order to estimate the speed of the shutter, it is only necessary to count these. These may be separated into blocks of ten by obliterating every tenth slot on the sector wheel, reducing the labor of counting. The images produced are shown in Fig. 3 for several different shutters.

FIG. 2.



Since the drum cannot be revolved at less than 400 r.p.m. with any accuracy or benefit to the motor due to the high braking necessary, shutter exposures of more than 1/50 of a second cannot be measured without overlapping of the image in one or more complete revolutions during the firing. To overcome this difficulty a "threader" *E* is used. (Fig. 4.) It is merely a flat piece of metal with a fine slit in it at right angles to the illuminated slit which can be swung into position between the drum and

FIG. 3.

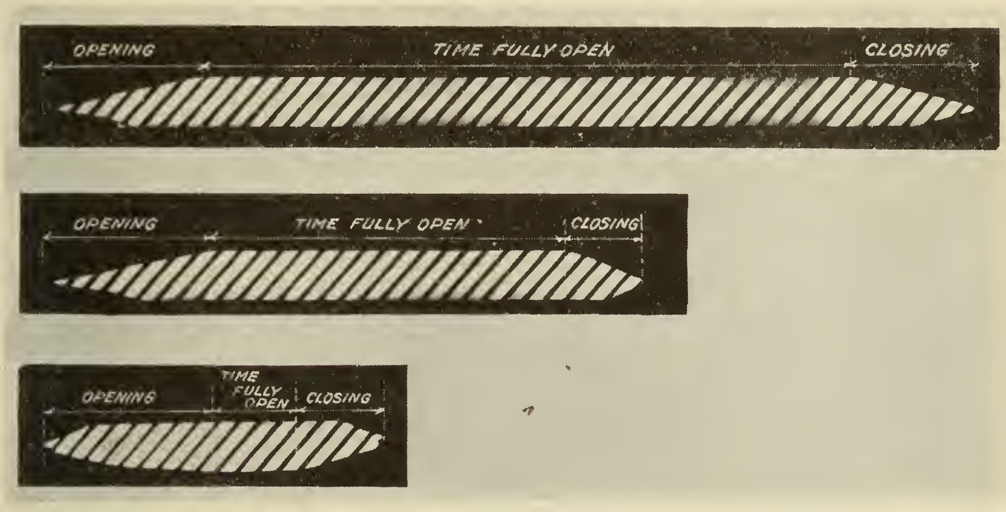
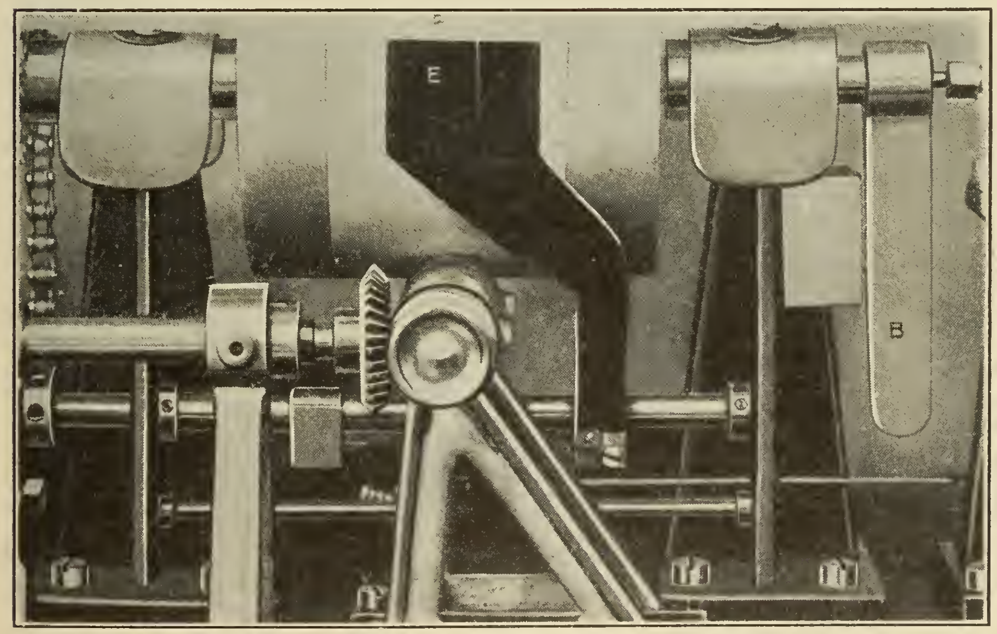
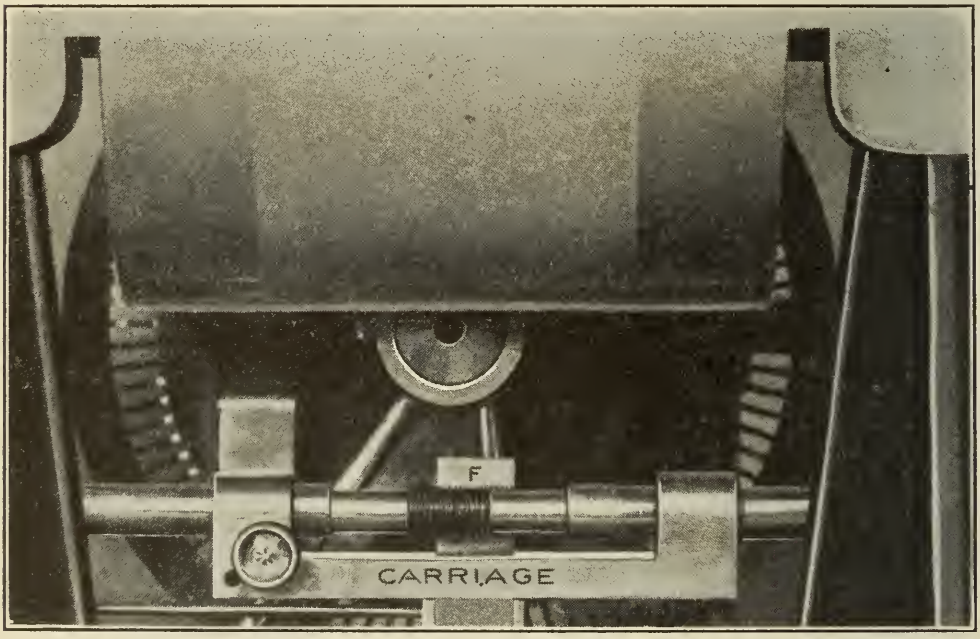


FIG. 4.



the sector wheel; its function being to permit only a small dot of light from the slit image to reach the drum. By means of a worm and a threaded finger the slit moves across the drum at the rate of 1/20 of an inch per revolution, thus threading a narrow dotted line around and around the drum as a bobbin winds a spool. The carriage carrying the threader is mounted on a shaft below the drum (see Figs. 5 and 5*a*). The screw is revolved at the same speed as the drum and motion translated to the carriage by the threaded finger *F*. The engagement and disengagement of this finger is controlled by the lever *G*, which also serves as a handle to draw the carriage back to its starting position at the left where it will remain until the finger is engaged by depressing the lever, when it travels to the right at the rate given. When this attachment is being used the drum is run at 625 r.p.m. and the speed of the exposure is then measured by the number of complete revolutions, *i.e.*, winding of the thread line plus the number of dots over the last complete revolution. The dots at 625 r.p.m. equal 1/1000 second each.

FIG. 5.



The actual technique of operation of the instrument for high speeds consists first of wrapping a piece of film tightly around the drum (in which position it can be affixed by merely moistening the ends and sticking them together), the shutter is set to the speed to be tested, the drum is started and the arc struck. The speed of the drum is regulated by means of the brake *B*, until the tachometer reads 1250 r.p.m. Then the shutter is fired. In measuring the slow speeds the same procedure is followed except that the drum is revolved at 625 r.p.m. and at the moment before firing the shutter, the lever *G* is depressed, thus starting the threader *E* on its trip across the drum.

Fig. 5a

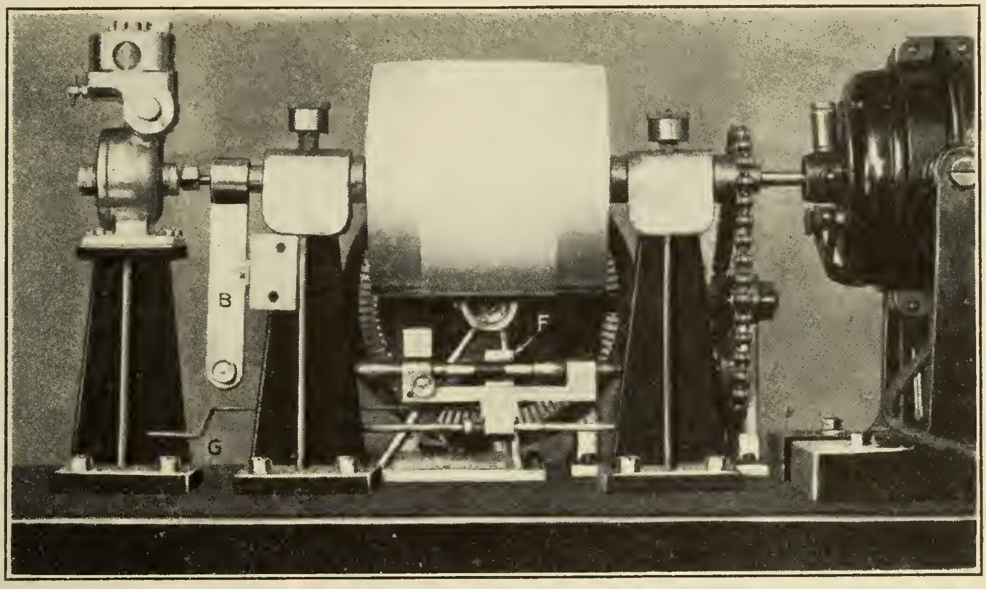
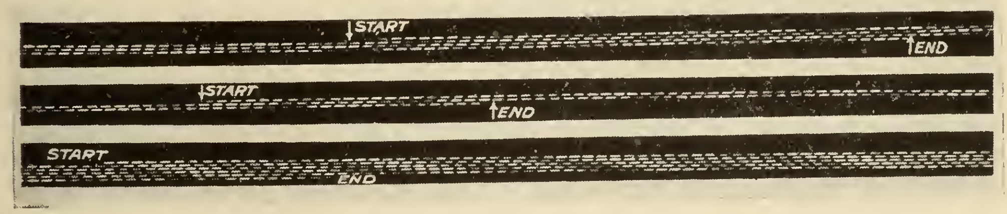


Fig. 6 shows the type of image produced by this threader.

Referring to Fig. 3, it will be seen the time of opening and the time of closing of the shutter is represented by the tapering ends of the image. The length of this taper varies with different makes and types of shutters and the diaphragm opening used. It is the factor in determining the efficiency of the shutter. However, it is of interest to note that for the same shutter and diaphragm the length of the opening and closing periods is unvaried

Fig. 6.



by a change of the speed setting of the shutter. The following table gives the result on some shutters tested.

TABLE

Shutter	Marked speed	Actual Speed	Time fully open	Time of opening	Time of closing
No. 1	1/150 = .0066	.0235	.0165	.0045	.0025
	1/100 = .01	.0220	.0150	.0045	.0025
	1/50 = .02	.0235	.0160	.0050	.0025
	1/25 = .04	.2490	.....	.....	.....
	1/5 = .2	.2980	.....	.....	.....
	1/2 = .5	.3290	.....	.....	.....
	1 = 1.0	.2640	.....	.....	.....
No. 2	1/300 = .0033	.0150	.0080	.0035	.0035
	1/200 = .005	.0230	.0155	.0035	.0040
	1/100 = .01	.0255	.0180	.0035	.0040
	1/50 = .02	.0295	.0130	.0030	.0035
	1/25 = .04	.0360	.....	.....	.....
	1/5 = .20	.1940	.....	.....	.....
	1/2 = .5	.5570	.....	.....	.....
	1 = 1.0	.7140	.....	.....	.....
No. 3	1/100 = .01	.0190	.0113	.0038	.0039
	1/50 = .02	.0220	.0151	.0034	.0035
	1/25 = .04	.0810	.....	.....	.....
	1/5 = .2	.1460	.....	.....	.....
	1/2 = .5	.3590	.....	.....	.....
	1 = 1.0	.5040	.....	.....	.....
No. 4	1/150 = .0066	.0155	.0060	.0035	.0060
	1/100 = .01	.0165	.0040	.0030	.0095
	1/50 = .02	.0220	.0095	.0030	.0095
	1/25 = .04	.0810	.....	.....	.....
	1/5 = .2	.1000	.....	.....	.....
	1/2 = .5	.2110	.....	.....	.....
	1 = 1.0	.4960	.....	.....	.....
	2 = 2.0	1.0300	.....	.....	.....
No. 5	1/250 = .004	.0056	.0017	.0021	.0018
	1/100 = .01	.0070	.0034	.0020	.0016
	1/50 = .02	.0328	.0287	.0020	.0021
	1/25 = .04	.0810	.....	.....	.....
	1/10 = .1	.1180	.....	.....	.....
	1/5 = .20	.2220	.....	.....	.....
	1/2 = .50	.4970	.....	.....	.....
	1 = 1 0	.8460	....	.....	.....

Shutter efficiency and the mathematics involved will not be dealt with in this paper. It is proposed in the near future to make a study of the influence of the various types and number of shutter leaves upon the efficiency and illuminating power of the shutter. The various driving mechanisms will be studied (*i.e.*, air, spring, and gear-driven) with a view to finding the most satisfactory method of actuating the shutter. These topics will be dealt with in a later communication.

RESEARCH LABORATORY,
July 28, 1916.

THE PRODUCTION OF LIGHT BY ANIMALS.*

BY

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THE LUMINOUS INSECTS.

The insecta share with the higher vertebrata the distinction of having emerged from a life in the water, to live in and breathe the atmospheric air. To be sure a considerable number of animals of other groups have also become land forms, independent of all water but drinking water. Such are found especially in the mollusks, worms and crustacea, but these air-living forms are but a very small proportion of the groups to which they belong and in most cases their life is conditional upon a considerable amount of external moisture.

The insects have become a group of extreme specialization in many directions and among these specializations is the light-producing power. The only other air-breathing organisms that are thus endowed are the fungi, or possibly more species of earthworm and several myriapoda. Even these latter may be in a way classed with the insecta.

The power of lighting is found developed in several families of insects in such a way that it appears to have arisen entirely independently. Thus we find it in some of the most primitive kinds as well as in others of much higher organization, and in this chapter the subject will be discussed in the following groups: (1) Order chilopoda of the class *Myriapoda;* (2) order collembola of the sub-class *Apterygota;* (3) order diptera of the sub-class *Pterygota;* (4) in several doubtful cases in which the luminosity may be due to external causes. In a succeeding part it will be discussed in the groups of coleoptera of the sub-class *Pterygota.*

The myriapoda are elongate animals of a varying number of segments. It is typical of them that they possess a number of integumentary glands secreting fluid materials that are discharged and used outside of the body. Some of these glands are unicellular, others resemble the typical crustacean integumentary gland,

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* Continued from page 843, vol. 181, June, 1916.

while in *Julis* the structure is sac-shaped. All these open through one or more pores in the side of each segment.

The substances secreted vary in a wide degree and they are all very highly specialized. Some produce odors, others poisons (as hydrocyanic acid in *Julis*) while in several species a photogenic material is produced that can be discharged and will then give light. It seems probable that in these forms and in the luminous earthworms we have the only examples of organisms that discharge a luminous substance into the air; most air-living forms burn the luciferin internally.

A great many observations have been made on this phenomenon, many of them very old and some so fragmentary or inaccurate that they have little value. We may divide the more careful of these records into four possibilities: First, those cases in which the myriapod had been eating or rubbing against the luminous mycelium of some fungus; second, the records that appear to show that the light came from a material secreted in the intestine, and that it was discharged from the posterior opening of the digestive tract at the time of illuminating; third, we have those cases where the light substance is reported to come from the lateral integumentary glands before spoken of; fourth, and last, some observers have seen the light, when stimulated, spread over the entire surface of the body.

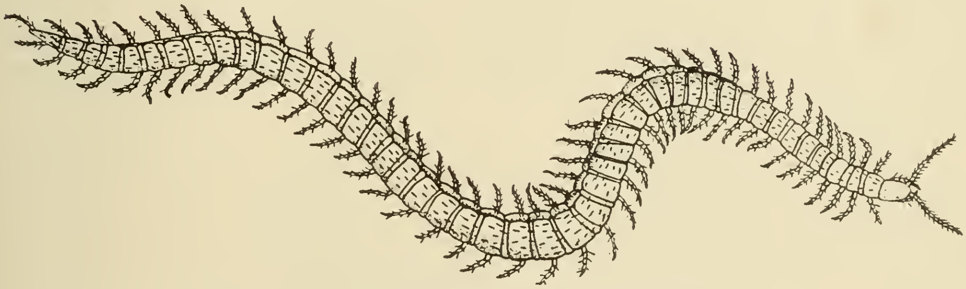
The luminous forms appear to be confined to some members of the order *Chilopoda*. When, however, so well known an observer as Molisch describes a luminous Chilognath we must feel sure that light was seen and this case seems to be one that would come under our first group; seems that the animal had eaten or become entangled in some way with portions of some luminous fungus. This idea becomes more certain when it is known that other specimens of this unnamed species were found to be without light even when strongly stimulated.

As an example of the second kind of observation we may record the report of Du bois who found a specimen of *Scolioplanes* (Fig. 1) under decaying leaves near Heidelberg and saw the luminous material issuing from the anal opening. He later described it as appearing in the same way from *Geophilus electricus* (Fig. 2). Macé described the luminous secretion as issuing from several large glands on the posterior end of the body. This view was also held by several other observers.

Thomas found a species of *Geophilus* crawling on a woodland path in the dark and gives us a very clear and definite account of the lighting process. The animal was being attacked by a number of ants that were biting it and trying to hold it back by seizing its legs and sides. The Geophilus was throwing out masses of a slimy light material from the sides of all its segments and the material was sticking to the jaws and bodies of the ants. They appeared to suffer from its contact and let go, running aimlessly in its wake, showing as moving points of light in the rear of the brighter millipede.

Audouin and Brodhurst observed *Scolioplanes crassipes* lighting and leaving a luminous trail on the ground. They also observed the light to spread all over the surface of the body when the living animal was disturbed and stimulated mechanically.

FIG. 1.



Line drawing of *Scolioplanes crassipes*. (After Brown.)

The above observations, most of them old and casual, show several points that we must read between the lines. First, we can no longer doubt that some individuals of several species *do* light at times. Secondly, the light is thrown off from the body and can be seen to continue to shine on the ground over which the creature crawls, on the enemies that attack it and on the fingers of those who handle it.

What we must look for now is some careful investigation of the best examples of the luminous forms by a careful and trained observer who can decide several questions that have been raised somewhat as follows: First, is there a species all of whose members of adult age and of either one sex or both will light consistently upon a definite stimulation, either throughout the year or at some definite season, as the breeding season, the cold or warm season or the wet or dry season? Second, the position and structure of definite glands and gland cells must be shown and the mechanism by which the light material is ejected. Our staining methods will do a great deal toward showing luciferine granules in the cells of such glands.

The two best studied forms so far are *Scolioplanes crassipes* from continental Europe and *Orya barbarica* from Northern Africa.

Scolioplanes crassipes (see Fig. 1) is found in many parts of Europe and in consequence is often seen by scientists in its native habitat where any light powers would be more easily observed. We have a considerable number of positive records of light-production as also a perhaps greater number of negative observations. And, to offset the positive records, we must remember two things; this myriapod often lives in the immediate neighborhood of several luminous fungi and it may eat them. Also we know of, or suspect, many other cases of organisms eating fungi or bacteria and shining by their borrowed light. On the whole we must assume for the present that *Scolioplanes crassipes* does light by its own powers but possibly not for the entire period of the year.

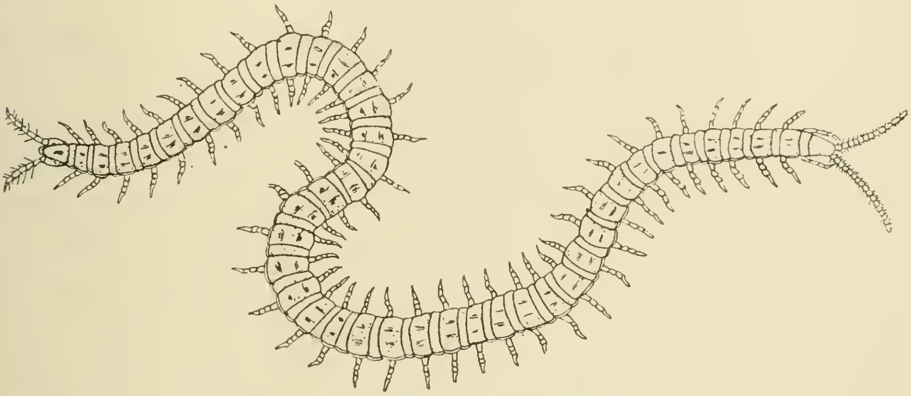
M. Huet, while walking in a garden at La Fere in France at about nine o'clock in the evening of mid-October, 1883, came suddenly upon a space about 40 centimeters square in which he saw, in the darkness, several curved luminous lines which seemed to move. He describes the light as of the color of that which appears on the edge of a burnt piece of paper. As most of us know such a light, it is reddish or orange in color. The following night and other nights he returned but saw no light.

The next year, again in October he visited the garden but saw nothing luminous. Finally, in 1885, on October 17, he came upon a number of the luminous streaks all assembled in a comparatively small space on the same ground. Picking up several in a mass of dead leaves he hastened to the house, dropping all but one on the way. This proved to be a myriapod, called by him *Geophilus electricus* (Fig. 2) and when taken into the dark again it appeared to give off a light, bluish-white in color from the entire surface of its body. The light substance adhered to the fingers when the animal was touched. It was brighter than the light seen by Huet on a dead fish (bacteria) but not so bright as the light of a glow-worm (larva or wingless female of a lampyris).

In later years he searched in the same spot and raked and dug in the humus and soil but saw no more of the luminous forms. This would appear to show that the animals shine only in October or in the fall, also that they had assembled for some reason, possibly for breeding purposes.

R. Du bois searched for the luminous myriapods in many parts of France and Germany. He found them among dead leaves and weeds growing along the railway and near an orchard in the neighborhood of the village of Handschuhsheim near Heidelberg. They were in motion and very bright. It was during a dry spell of weather and in the fall of the year, September or October. Having placed the animals on a piece of paper and examining them carefully with a hand lens he saw the luminous material appear as small moist masses that stuck to the paper in the animals' trail and soon ceased glowing and dried up. Each mass was irregularly shaped and appeared to consist of very fine particles, like the finest sand, held together by a tenacious mucus. When attempting to remove some of the dried material he accidently pulled out some of the lower digestive tube and saw luminous material upon or in it. He took this to mean that the material comes from the intestine or some of its glands but did not mention that it might have come from integumentary glands opening on the animal's outer surface and bound mechanically to the tissues of the intestine which is large and nearly fills the body at this point.

FIG. 2.



Line drawing of *Geophilus electricus*. (After C. L. Koch.)

Besides emitting a luminous substance the creature had a glow that seemed to come from an internal luminosity and to be continuous. This weaker glow was visible along the sides of the body and would seem to indicate the presence of luciferine in an active state in the integumental glands.

Du bois was not able to find by dissection any specific light tissues and came to the conclusion, in this paper at least, that the presence of light was accidental and due to some unusual or abnormal physiological condition. He did not attribute it to parasites (bacteria or fungi) or to materials eaten. He did find, by microscopical methods, certain intestinal cells that seemed to be " degenerating " and that contained granules similar in size and form to the granules that appear in the discharged secretion.

Another observer found the millipedes crawling in the superficial cracks and depressions on the trunk of a pear tree in his garden one damp warm night. They shone as streaks of light and their presence in some numbers on one tree would point to the breeding time.

In conclusion we may say that none of the studies of light productions made on *Scolioplanes crassipes* have been complete or satisfactory but that the existence of the power appears to have been definitely established and the work should be taken up by some one who has the opportunity presented by more and better material than has yet been found. The interesting form *Orya barbarica* was discovered to be a light-producing form more recently than was *Scolioplanes.* Raphael Blanchard and J. Gazagnaire first observed it lighting in April and in May respectively of the year 1888, at El Kantara and at Nemours in Northern Africa.

Professor Du bois, not being able to secure a sufficient supply of *Scolioplanes,* went to Africa (Algeria) in 1892 for the purpose of studying *Orya* and collected them, with no apparent difficulty, in the lighting condition. He observed that the light secretion was thrown off from the ventral surface of the animal as a slime that rapidly dried on the hands. Having cut and stained sections of the creature's body, he discovered glands in the integument. These glands possessed ducts that opened on the sternal and episternal plates of the segments. From these came a substance that was yellowish in color and with a peculiar odor of its own. The glands were pyriform in shape and were unicellular, evidently modified cells of the hypodermis. In their cytoplasm could be seen granules of a rounded oval shape and these same granules were also seen in the discharged secretion.

The granules were soft and in the center of each was a fluid-filled space in which appeared a single refractive point or small speck. The material of the granule appeared to be a fatty substance but failed to stain black in osmic acid as a true fat would. In response to rough tests it appeared to be a protoplasm or albuminoid.

Some of the freshly discharged material was placed on a glass slip under the microscope and, while still glowing, was examined with high powered lenses. As the light glowed the refractive speck was seen to develop into a crystal or group of crystals that continued to grow in size as the light continued to be emitted. It is well known to chemists that the crystallization of many substances is accompanied by light and Du bois decided that the light from *Orya* was a crysto-luminescence of this process. He even went so far as to conclude that this was the origin of the light in all luminous forms and to give up his theory of the presence of a catalytic agent, luciferine, although, he subsequently reconsidered this idea, his greatest contribution to the question of the theory of light production in animals. Such a crystallization may be the origin of animal light with the crystals so small that they are not visible. And the catalyzer may still be necessary for this particular process of crystallization.

THE COLLEMBOLID INSECTS.

This primitive order of insects (Fig. 3) is distributed all over the world and is best known to the general observer in two forms that come into our life, the " spring-tails " or " silver-fish " that occur in books, old papers and any other place in the household where they can find paste or glue to eat; also as the small blue-black forms that live on the beaches of both fresh and salt water where they have a curious habit of congregating in masses on the surface of tide pools and other small beach pools. None of these two kinds are luminous, however, but are noticeable on account of their comparatively larger size.

The larger part of the group are of extremely minute size and live on the leaves of living plants and among masses of dead leaves and wood in the forests and meadows where they can be damp and secure from disturbance by their enemies. Some are so small as to be scarcely visible to the naked eye. It is among these *Thysanura* that light-producing members have been seen by several observers among whom are Allman, Lubbock, Tullbirg, Heinrich, Molisch, Du bois, Ludwig, Templeton and others.

Allman seems to be the first (in 1850) to have observed light in a species, *Amphorura finctaria*, in the neighborhood of Dublin in the month of February. Mangold uses the name *Anuphorus* or *Lipura finctaria* for this species. Allman found the creatures in thick heaps of manure which are abundant in that locality.

FIG. 3.

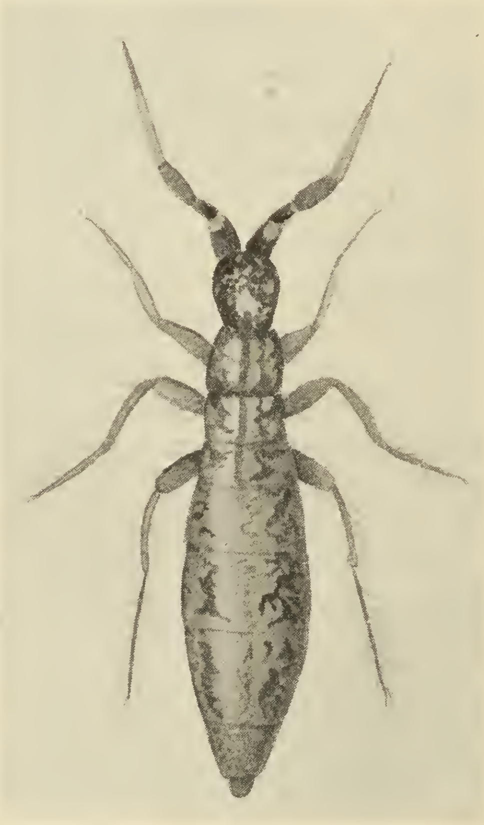


Figure of a poduran. (After Guërin and Percheron.)

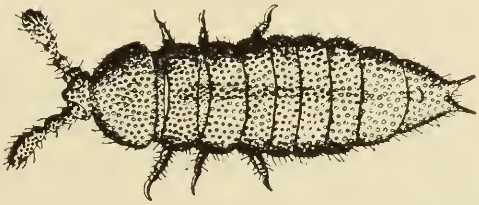
Du bois observed and described the same phenomenon in the neighborhood of Heidelberg in 1886, while he was searching in the night time for luminous myriapoda. Fig. 4 shows the form that he studied, *Lipura noctilnea.* He found them in the same hop field and same masses of dead leaves in which the luminous myriapoda were found. This is important as showing that they were exposed to the same chances of infection with any luminous mycelia growing in their surroundings that the myriapoda were.

Also the light of the myriapoda might have come from eating the bodies of the podurans. This seems rather unlikely, however, as the digestion process would in all probability have destroyed the light cells very quickly.

The insects appeared in the freshly turned-over humus as a large number of tiny blue-green stars or points of light. They were so small that they could not be seen at any distance. One had to look from a distance of not more than forty centimeters in order to see them clearly. The general impression that they gave was much that of seeming sea water with its numbers of noctilucas or other peridinidæ.

Under a magnifying glass the podurans were seen to give off the light from all over their bodies. They were only 2-3 mm. long and slender. This light was continuous, an important point, and was augmented by mechanical and other stimulations. When the bodies were crushed it appeared that the entire mass gave off light. While it is true that it appeared to do so, it is more probable that the appearance was due to a mixture of luminous tissue with the non-luminous portions of the body. At the same time it tends to show that the light organ is large and extensive in proportion to the size of the body.

FIG. 4.



Drawing of the luminous poduran *Podura noctiluca.* (After Henneguy.)

An application of litmus paper to the mass showed an acid condition. This might be due to a number of parts and does not seem to signify much in this particular case. The same seems to apply to Du bois' second experiment of placing some of the material on the tongue when distinctly acid sensations were experienced as well as a strong odor. The odor at least most probably came from some scent glands rather than from the light organs.

Lipura armata was studied also but gave no sign of luminous activity.

Upon dissecting the body of a luminous form with needles, it was observed that the tissues showed lumps of a peculiar refractive appearance. Under crossed Nicols prisms these are described as giving the same appearance as the luminous tissues of other animals. Also they contain granules resembling the granules of light cells in the fire-flies. It should be easy to determine by microscopic methods if these are the light organs or not. This does not appear to have been done.

Ludwig discusses Du bois' paper and the possibilities of finding the light power among other members of the podura. Having collected many species himself he suggests that they be studied again by some one with reference to a possible luminosity. Many of the species live on plant leaves. In this regard the writer calls to mind the story of a friend who said that on his way home one night he had occasion to urinate on some weeds by the wayside. When drops of the fluid fell on the leaves a number of bright luminous spots appeared which might have been some luminous podurans stimulated into activity by the acid fluid.

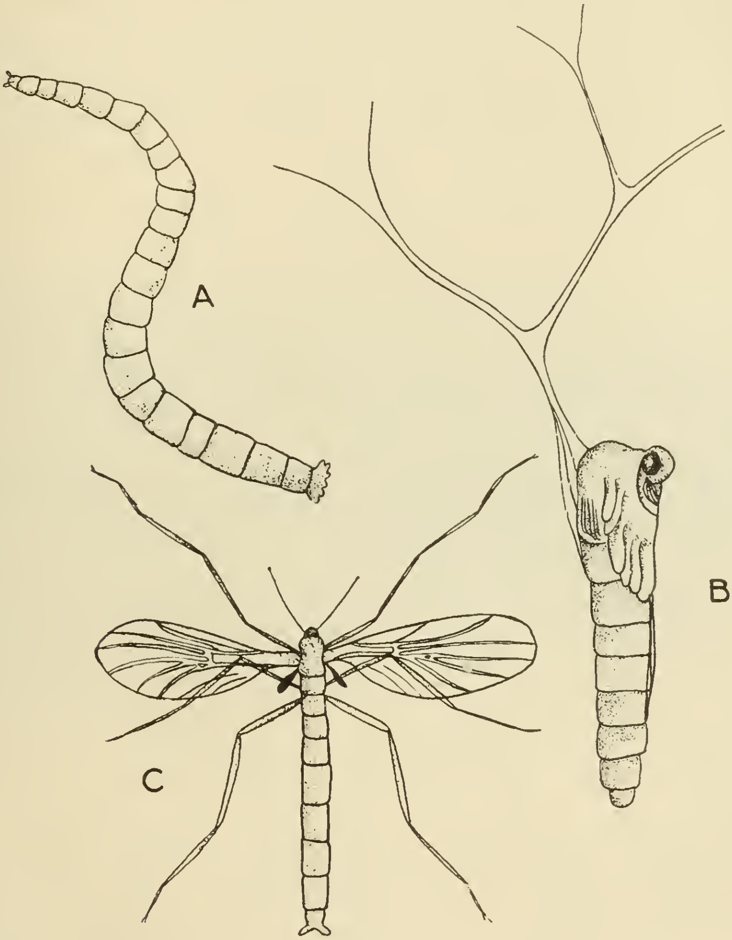
TIPULID FLIES.

While our scanty and somewhat fragmentary evidence as to the lighting of some of the preceding forms leaves us in partial doubt as to their autogenous light production, we find in the case of *Bolitophila luminosa,* a tipulid fly, that the evidence is complete and well authenticated as to their lighting power. This fact has been observed by Meyrick, Hudson, Cheesman and other New Zealand naturalists, and, during a trip to the caves of New Zealand by Conklin, Wheeler and other members of the scientific groups visiting that country at the invitation of the Royal Society of London in September, 1914. Wheeler and his pupil, M. Williams, published an account of this form in 1915 in the Journal "Psyche," dealing principally with the light organ as found in the adult larva of this form. From this and the preceding accounts we find ourselves in possession of a fairly good knowledge of the subject. Fig. 5 shows the larva pupa and imago of this fly.

The larva lives in caves or under the hollow banks of streams in dark woods. It is of the form and general appearance of most fly larvæ, with a pointed head situated on the thinnest end of the elongate body and with the chitin of the jaws and surrounding mouth-parts showing a brown to black color, the only color visible on the whitish, translucent body.

The larvæ live on a series of thin, moist, glutenous threads, spread as a scanty net in connection with the surface of the rocky or hard earthen bank of the cavern which they inhabit. According to Hudson one strand of the net is longer and straighter than the rest and forms an axis of the greater length of the web. The larva spends most of its time on one end of this main axis with its body partly inside of a burrow or cleft in the rock. It is said to retreat into this cavity when disturbed.

FIG. 5.

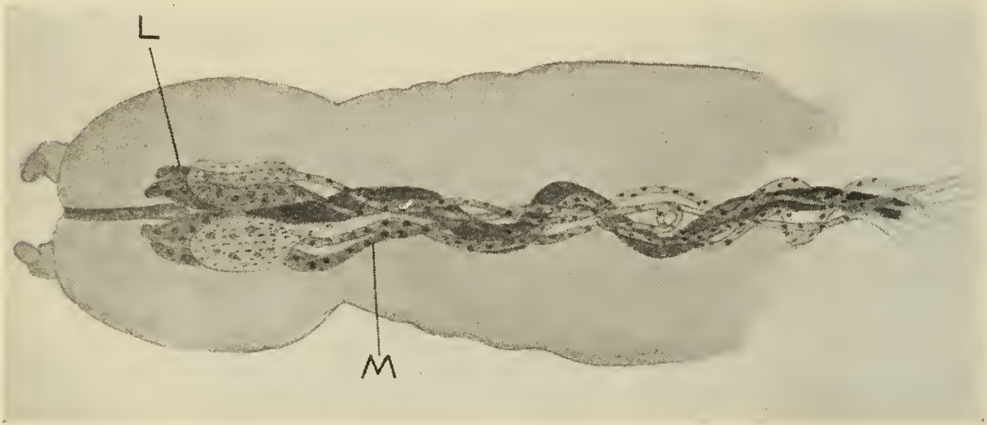


A, larvæ; B, pupa, and C, imago of the tipulid fly, *Bolitophila luminosa*. The pupa is suspended from the glutenous net that it constructed as a larva. (After Hudson.)

As to the food eaten by the larvæ, it was thought by Hudson to consist of the dead or low organic forms of life in its surroundings, but Wheeler showed that the larvæ catch living insects in the sticky web and use them for food as Meyrick has stated. These larvæ are quite numerous in some of the caves and tunnels and shine like hundreds of bluish-green stars above the observer who has entered such a place. The light appears to glow rather steadily but is evidently under the animal's control because if disturbed they shine with extra brilliancy for a few seconds and then suddenly shut off the light and retreat from the web into the hole or cleft near which it is built.

Wheeler examined the larvæ in the living state in the tunnels and caves and was able to locate the light organs with a strong pocket lens. The luminous organs could be plainly placed as four thick, parallel rods, closely applied to one another on the ventral surface of the rectum. These rods were in the somewhat dilated, terminal segment, identified by Wheeler as the eleventh abdominal segment because it bore a pair of small jointed cerci. The luminous rods were parallel, slightly curved and ran parallel to the intestine and the length of the larva. They were arranged in the form of a plate in the longitudinal as well as the lateral direction. The slight curve of the rods rendered this plate somewhat convex on its ventral surface and concave on its dorsal surface. They gave off a bluish-green light, much more intensely from the dorsal surface than from the ventral. The reason for this will appear later.

FIG. 6.

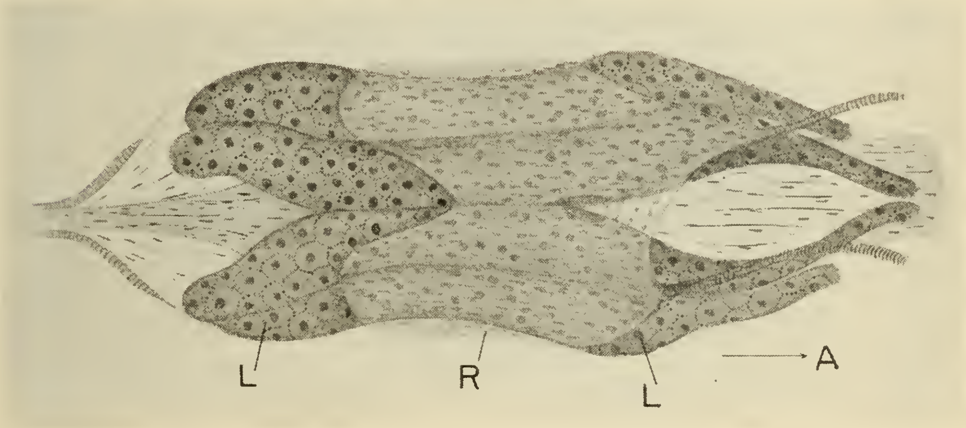


Dissection of the posterior part of the body of the larva of *Bolitophila*. Seen from ventral surface. L, luminous organ; M, Malpighian tubules originating from intestine. (After Wheeler and Williams.)

Wheeler and Williams dissected some of these larvæ and sectioned and stained others. This showed that the four rod-shaped light organs were the distal ends of the four long, coiled malpighian tubules found in all insects as the excretory organs. They are tubular invaginations of the simple epithelial wall of the lower intestine and vary in number to a considerable extent in the different species of insects, six and eight being common numbers, while they may be as few as two or extend into very large groups. In the diptera there are usually four.

In *Bolitophila* these four tubules are given off from a fairly anterior point (see Fig. 6) and, after running forward a short distance, turn and go posteriorly, having a curved path with several loops that straighten out when the creature extends its elastic body. The tubules, of generous size at their point of origin, widen their diameter somewhat during their anterior course and then gradually become smaller as they pass posteriorly. As they narrow they assemble on the ventral side of the gut, finally becoming very narrow and arranged horizontally just before they suddenly widen again into the four short, thick rods that form the light organ. Fig. 6 shows these, and Fig. 7 shows them on a larger scale.

FIG. 7.

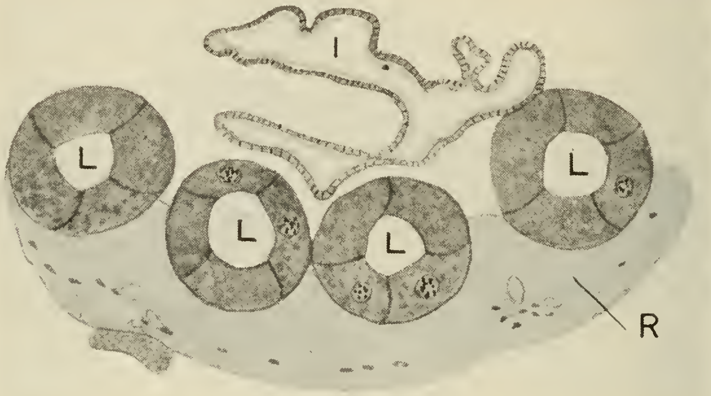


Enlarged view of luminous organ seen from ventral side. R, reflector; L, luminous organs. A, anterior direction. (After Wheeler and Williams.)

Sections of the various parts of the tubule show it to be a typical insect excretory organ with the large, fleshy cells and striated distal border lining a wide, flat, narrow lumen. Sections down in the light-producing portion show that this structure has been substantially changed although both cellular wall and lumen are continuous with those of the excretory portion of the gland. The cytological structure of this light-producing portion has not been as closely studied as is desirable. It can be said, however, that the cytoplasm is secreting large masses of a granular material and that these granules are undoubtedly granules of luciferine, or, as E. N. Harvey has recently named it for reasons to be explained in a following chapter, photophelein.

Of great interest is a mass of modified connective-tissue found on the ventral surface of the plate-like group of four rod-shaped tubes. This tissue is the reflector, as is evidenced by the fact that the light appears much brighter when seen from above. It has not been studied sufficienty to show what material has been developed by the cell to perform the reflecting function. If we refer to the fire-flies (Lampyridæ) we may suppose that crystals of some urate are thus used but further studies may show some other substance. The reflection is not as complete as in the lampyridæ and this appears to point to some important difference. The reflecting layer does not completely cover the light glands on their ventral surface as Fig. 8 will show.

FIG. 8.



Transverse section of luminous apparatus of larva of *Bolitophila*. L, luminous organs; I, intestine; R, reflecting tissue showing tracheal tubes (hollow spaces) and muscle fibers (dots); (After Wheeler and Williams.)

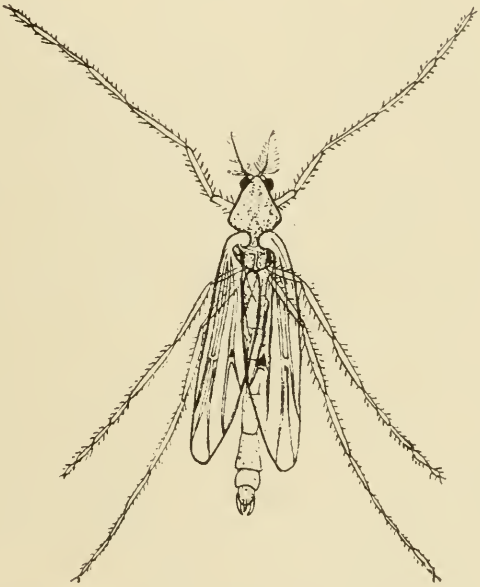
The tips of the luminous portion of the malpighian tubules are not complete, the lumen being separated from the body cavity only by a thin plate of tissue which, owing to its lack of cytoplasmic body, cannot have any photogenic function.

Not only is the larvæ of this fly luminous, but also, as Hudson has shown us, the pupæ and the imago show a light. Unfortunately we have no histological studies as yet published that indicate the structure of the light glands in these subsequent forms. Very possibly the same malpighian tubules are retained to perform the function, but it is also quite possible that another and entirely different set of cells are developed as light organs. As will be seen in the next chapter this occurs in our lampyridæ and most probably also in *Phengodes* and *Pyrophorus*. The light appears in the same part of the abdomen in both pupæ and imago as it does in the larva.

CHIRONOMID FLIES.

Another family of tipulid flies, the chironomidæ, of which there are over 500 species in Europe alone, show some members which are said to be luminous (see Fig. 9). Osten Sacken described such forms in 1878 and Brischke in 1876. While Tarnani has discussed them in 1908, his paper is unfortunately written in Russian and was inaccessible to the writer who gets his information from Schmidt's careful paper published in 1895.

FIG. 9.



Drawing of a chironomus fly. (After Miall.)

Schmidt visited Lake Issyk-Kul in Russia and a lake near Prshewalsk in the summer of 1894 and found there flies on the wing and exhibiting their light. Swarms of them were hatching from the water and flying over the beaches. More than one species was showing the light and three such were identified as *Chironomus intermedius, C. plumosus* and *C. tendens.* Not all the members of any one species showed the light but only a limited proportion. The light thus shown was not a flashing one, but a continuous light that appeared to shine from every part of the body from some internal source.

This seems to point to an artificial condition rather than to an autogenous light production. Further, this view is supported by the fact that the luminous individuals were distinctly sluggish both on the wing or when they alight on wood or shrubbery. They were prone to alight and remain quiet while their non-luminous fellows were flying. The light was surprisingly bright, being compared to that of a fire-fly.

We evidently have to do here with a case of disease, probably caused by fungus or bacteria. One thinks at once of the luminous *Talorchestia* mentioned in the chapter on crustacea in which we have proof that bacteria in the blood and digestive tube are the source of the illumination. There is the difficulty here, however, of imagining any luminous bacteria that live in or around a fresh water locality. To be sure they would find enough sodium chloride in the tissues of their host to be able to illuminate and, in the intermediate stages, they might breed and live in the non-luminous condition on other media found in or near the waters of this region. Other localities are known in Germany where these species of the chronomidæ are common, but where no light has been observed in connection with their life history.

The larvæ live in mud and vegetable débris on the bottom of the ponds and lakes. The flying was in early summer.

Eaton has mentioned a luminous mayfly from Ceylon, and Gummerthal a luminous fly larva from Russia, but these reports require further investigation and study.

Autogenous light has been attributed to several other insects. Persistent reports of the luminosity of the lantern-fly, *Fulgora,* by Bowring, Brauner, Distant, Evans, Gounelle, Hancock, Hoffmansegg, Moufflet, Smith, Wesmael and Westwood have been published. While many have asserted that the light has been seen by other (mostly non-scientific) observers, the question is not settled, and certain other observers have tried and have failed to see it. The idea seems to have arisen, not from seeing light, but from the fact that a large hood on the head is shaped like a lantern in which some ignorant observer has imagined that he saw a light, being prompted to this idea by the name.

The larvæ of a moth or butterfly has been reported as luminous by Boisduval, and other observers have reported light as coming from other beetles than the elatyridæ and lampyridæ.

(*To be continued.*)

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

A STUDY OF ELECTROMAGNET MOVING COIL GALVANOMETERS FOR USE IN ALTERNATING CURRENT MEASUREMENTS.[1]

By Ernest Weibel.

[ABSTRACT.]

The increasing use of alternating current bridge and potentiometer measurements emphasizes the need of a detector or galvanometer with characteristics similar to those of the sensitive galvanometers used in the corresponding measurements with direct current. The vibration galvanometer is fairly satisfactory at commercial frequencies and at telephonic frequencies the telephone receiver is used, but in both cases the performance fails to equal that of the direct current galvanometer. This paper gives the results of a study of the electromagnet moving coil galvanometer which has led to the construction of instruments with sensitivities much greater than those previously obtained and equal to those of the best direct current moving coil galvanometers.

The theory of the instrument is developed and is based on the equation of motion which is deduced by considering all of the torques acting on the moving coil in the alternating magnetic field. The equation of motion is first expressed in terms of the intrinsic constants (the moment of inertia, the moment of damping, the moment of restoration and the moment of displacement), and the deflection, velocity, acceleration and current in the moving coil. The current is then known from the resultant electromotive force in the moving coil circuit and the moving coil circuit constants. It is necessary in computing the resultant electromotive force to consider not only the impressed but also the induced electromotive force. This induced electromotive force is in part due to the motion of the coil in the magnetic field, causing electromagnetic damping, and in part due to the alternation of the flux linking with the coil, causing a current which results in a control torque in addition to that of the suspensions. It is found that the motion may be underdamped, aperiodic, or overdamped, depending upon the magnitudes of the intrinsic constants and the constants of the moving coil circuit. In case of a sinusoidal magnetic field and a non-inductive moving coil circuit the performance is analogous to that of the permanent magnet moving coil galvanometer for direct current. The operating constants of importance are—the period, the external critical resistance, and the sensitivity. The deflection is proportional to the component of the electromotive force in phase with the magnetic field. In order, therefore, to be sure that no deflection means no detectable electromotive force it is necessary either to know that the electromotive force is in phase with the magnetic field or to change the phase of either the excitation or the current or currents furnishing the unknown electromotive force.

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* Communicated by the Director.

[1] Scientific Paper No. 297.

The operating constants are given in terms of the intrinsic constants so that, if these are known, the performance can be predetermined for the conditions of use. A method of measuring the intrinsic constants has been developed. Equations are given for use in the design of instruments to give definite operating constants.

If the moving coil circuit contains reactance the performance of the instrument is changed. The paper shows how the operating constants depend upon the constants of the external moving coil circuit. Condensive reactance lengthens the period and inductive reactance shortens it. These effects as well as the effect of electromagnetic damping increase with decrease of the impedance of the moving coil circuit. It is, therefore, possible to vary the performance considerably by changing these constants and by changing the excitation.

The effects of harmonics in the magnetic field on the selectiveness of the instrument is shown and it is usually possible to increase the selectiveness sufficiently by the use of electrical resonating systems in connection with either the excitation or moving coil circuits.

The paper contains the descriptions and gives the performances of four instruments. The results indicate that the theory as given is fundamentally correct and therefore serves as a good basis for the design and use of instruments of this kind.

THE RECOVERY OF PARAFFIN AND PAPER STOCK FROM WASTE PARAFFIN PAPER.*

By W. H. Smith.

[ABSTRACT.]

A PROCESS is described for the recovery of the paraffin and paper stock from waste paraffin paper, employing a vertical steam boiler, tanks for receiving the paraffin and a beating engine. The waste is pulped in the boiler, with exhaust steam, in order to separate the paraffin from the fibers. After the treatment, the wax rises to the surface and is drawn off with the hot water through a screen, the stock settling to the bottom of the boiler. The stock is transferred to a beating engine and treated with hot water, soap, and turkey red oil, or with caustic soda, depending upon the amount of ink in the material. The turkey red oil assists the residual paraffin to coalesce and rise to the surface. By means of a metal cylinder, internally chilled with cold water, and partly submerged in the hot water of the beater, the paraffin remaining in the stock is readily collected. Paper prepared from the recovered stock was free from wax and satisfactory in every respect. Practically all of the paper stock is recovered, but about ten per cent. of the paraffin in the waste is lost during the process.

TESTING OF CLINICAL THERMOMETERS.

[ABSTRACT.]

THE Bureau of Standards has just completed a revision of Circular No. 5 on the "Testing of Clinical Thermometers." This new edition, which is the third so far, announces the adoption of new regulations, effective January 1, 1917, governing the testing of clinical thermometers. Past practice was to issue certificates containing tables of corrections at four points, 96°, 100°, 104°, and 108° F.; the new certificates will be issued only for thermometers correct within 0°.1 F. at normal (98°.6); and 0°.2 at 104°, and will contain the statement that the thermometer is correct within these tolerances.

The circular contains a full description of the method of test-

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* Technologic Paper No. 87.

ing clinical thermometers and considerable matter of general interest concerning these instruments.

The question of accuracy in clinical thermometers is obviously an important one. The clinical thermometer bears the same relation to the physician as the weighing scale does to the merchant, but in a way the former is vastly more important, as it has to do with life itself.

It has been estimated that over a million of these little instruments are manufactured each year to replenish the supply, for a clinical thermometer is delicate and usually short lived. Unscrupulous manufacturers, taking advantage of this never ceasing demand, place on the market thousands of unreliable thermometers, which, on account of their cheapness and the fact that their defects are almost impossible of detection, find ready sale.

It is obvious that the Bureau cannot inspect all these thermometers for it tests only those that are voluntarily submitted. This circular calls attention to the fact that thermometers of doubtful accuracy may always be checked at this Bureau, and that when a thermometer is offered for sale with a Bureau of Standards certificate, its reliability can not be questioned. If instruments of a high quality are thus demanded, in time the unreliable article will no longer be manufactured.

NATIONAL ELECTRICAL SAFETY CODE.

[ABSTRACT.]

THE Bureau of Standards, Department of Commerce, has recently published the second edition of Circular No. 54, entitled the "National Electrical Safety Code."

The increasing application of electrical energy for various commercial and private uses brings a rapidly increasing number of persons in contact with or into close proximity to electrical equipment of various kinds. In many cases the persons working on or near such equipment are not familiar with the hazards involved. It is also becoming better appreciated that in many cases such equipment may readily be provided with more adequate protection against accidents than has heretofore been the general practice. The use of safer construction and better insulation methods has, in fact, been found to be a prominent factor in increasing the use of electricity.

The National Electrical Safety Code has been developed by the Bureau of Standards after some three years of study of the many hazards involved, aided by the active coöperation of the many interests which such a Code affects, including the electrical utilities serving the public and the administrative authorities, such as state utility, accident, and labor commissions, and accident and compensation insurance companies, who are particularly interested in the problems of accident prevention. The Safety Code gives in detail requirements based upon principles recognized as correct in the experience of a great number of public utility companies, the recommendations of inspectors for commissions, municipal authorities and insurance companies in their studies of accident prevention, as well as those indicated by an analysis made by the Bureau of a great number of electric accidents reported from all parts of the country. In addition to those rules which appear as requirements, there are many which are merely recommendations, but which will very often be observed where the maximum degree of safety is desired.

The Safety Code is subdivided into four principal parts. These several parts contain rules and recommendations applying to the several phases of the electrical industry, as follows: Part 1, Electrical supply stations for the generation of electrical energy; Part 2, Overhead and underground lines for the transmission and distribution of electrical energy and intelligence; Part 3, Utilization equipment for the conversion of electrical and mechanical energy, and for light, heat, and electrolytic processes; and Part 4, rules to be observed in the operation of electrical equipment and lines. There is also a section on the methods of protective grounding. These rules apply generally without regard to whether the system supplies electrical energy commercially or is a portion of a manufacturing plant.

In introducing the National Electrical Safety Code the Bureau of Standards earnestly recommends that it be used on trial for a period of a year or more before it is enforced in a formal manner. During such period of actual trial and study on the part of administrators and those to whom the rules apply, it will be possible to observe how it operates in practice, and in what respects it should be modified. Constructive criticism is requested in order that subsequent editions may be made of the greatest practical value to the electrical industry.

SPECIFICATION AND TESTS OF THE TRANSPARENCY OF PAPER AND TRACING CLOTH.

THE Bureau of Standards, Department of Commerce, has just published a Circular under the above title (Circular No. 63). It describes a method of quantitatively specifying transparency for practical purposes, states the form of the specification, and gives a description of the apparatus used to make measurements.

Aluminum Castings. P. E. MCKINNEY. (*Proceedings of the American Institute of Metals,* September 11–15, 1916.)—It is a well-known fact that pure aluminum is entirely too soft to produce satisfactory castings for most purposes, and it is the universal practice to stiffen up the alloy with some hardening element. Probably the most widely used hardener for aluminum is copper which is used at the rate of about eight per cent. of copper to ninety-two per cent. of aluminum. Zinc and tin are also frequently used as hardeners. The use of these hardeners is attended with some well recognized objections. In the first place, the addition of eight to ten per cent. of hardener partially defeats the purpose of using aluminum in that the specific gravity is materially increased. The hardened metal, while fairly strong, has a decided tendency to brittleness and the alloys are in most cases less resistant to corrosion than either of the component metals. Hot shortness, in the case of intricate castings, is another feature attendant to the use of these hardeners.

In the 9th Annual Report of the Alloys Research Committee, Dr. W. Rosenhain and Mr. F. C. A. H. Lentiberry have published some very interesting data on the influence of manganese on aluminum alloys, which demonstrates beyond a doubt that these combinations have great promise in the production of light alloys. Various combinations containing manganese, with or without copper and with a minimum aluminum content of ninety-five per cent., have been used in actual foundry practice for the past two years with most gratifying results. The use of manganese in relatively small quantities hardens and strengthens the alloy without destroying its ductility as is the case with copper or zinc. The machining properties are excellent and the comparatively small amount of hardener used makes possible a specific gravity in the finished alloy of 0.35 to 0.40 less than that of the ordinary No. 8 alloy. When properly made, these alloys are practically free from hot shortness and the most intricate castings can be produced with comparative ease.

NOTES FROM THE RESEARCH LABORATORY, GENERAL ELECTRIC COMPANY.*

THE EVAPORATION, CONDENSATION AND REFLECTION OF MOLECULES AND THE MECHANISM OF ADSORPTION.[1]

By Irving Langmuir.

PART I.

It is suggested that the reflection of mercury atoms described by Wood (*Phil. Mag.*, 30, 300 ('15)) can be attributed as well to condensation, with subsequent reëvaporation when the plate is sufficiently hot. The distinction between the two explanations, which will become apparent at intermediate temperatures, consists in that if it is reflection, the number leaving the plate will always be proportional to the number striking, but if it is reevaporation the number can never exceed the normal rate of evaporation of mercury in a perfect vacuum.

Experiments are described which seem to indicate that molecules and atoms of all kinds show little tendency to reflection from solid surfaces. Of metal vapors condensing on surfaces of the corresponding metal, not over one atom per thousand is reflected. Molecules of permanent gases striking surfaces covered with adsorbed films of gas molecules give some evidence of reflection which may reach 81 per cent. for hydrogen from a surface covered with hydrogen at high temperatures. This appears to be the maximum possible and the amount for other gases is less than 50 per cent. no matter what the nature of the solid surface.

Evidence is drawn from the results of experiments upon the rate of evaporation of tungsten filaments, the vapor pressures of platinum, molybdenum, and silver, the electron emission of tungsten. It has been further shown by experiments on the "accommodation coefficient" of hydrogen that the reflectivity changes only slightly with temperature.

A statistical consideration of heterogeneous chemical reactions has shown that the fraction of the number of oxygen molecules striking heated tungsten or molybdenum filaments which undergo chemical reaction increases rapidly with temperature, becoming 0.4 at 3000° K., and apparently reaching at higher temperatures a limiting value of 0.7. Hence the reflectivity cannot exceed 30 per cent., and probably the small values of the fraction at low temperatures is due to an inactive condition of the surface rather than to a higher reflectivity.

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* Communicated by the Director.

[1] *Physical Review*, 8, 149–76 (1916).

Hydrogen at pressures so low that the normal free path is several meters, converted into atomic hydrogen by contact with heated tungsten, can diffuse long distances through glass tubing at ordinary temperatures but cannot pass even short distances through tubing cooled by liquid air.

Study of the reaction between hydrogen and oxygen on a platinum surface has shown that here the reflectivity of oxygen molecules cannot exceed 47 per cent. and of hydrogen 59 per cent., even at 900° K. The study of a large number of other heterogeneous reactions seems to bear out the conclusion that the fraction of the gas combining approaches unity except in cases where the surface of the solid is largely covered with inactive material.

A detailed mathematical consideration of the energy relations involved and of certain other atomic properties develops a method for calculating the maximum amount of reflection and it is concluded that this can in no case exceed 99 per cent., and is in all probability not more than 90 per cent.

THE CONSTITUTION AND FUNDAMENTAL PROPERTIES OF SOLIDS AND LIQUIDS.[1]

By Irving Langmuir.

PART I. SOLIDS.

THIS article is too detailed and specific for abstracting. The following is the author's summary:

1. The work of the Braggs on crystal structure is reviewed from the viewpoint of the chemist and the relation of this work to theories of chemical constitution, such as those of Werner, Stark, J. J. Thomson, and Lewis, is discussed in detail.

2. It is concluded that the substances whose structures have thus far been studied by the X-ray spectrograph are not repre-

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[1] *Journal of the American Chemical Society*, 38, 2221–95 (Nov., 1916).

sentative of compounds in general. Only polar compounds have been studied.

3. Solid polar compounds are, in general, built up of atoms bound together by secondary or residual valence. The whole crystal must be regarded as a single molecule.

4. Solid non-polar compounds consist in general of "Group Molecules," in which the atoms are usually held together by primary valence. These group molecules in turn are bound together by secondary valence to form a large "Crystal Molecule," which includes the whole solid mass.

5. There is no present justification for dividing interatomic (or intermolecular) forces into *physical* and *chemical forces.* It is much more profitable to consider all such forces as strictly chemical in nature. Evaporation, condensation, solution, crystallization, adsorption, surface tension, etc., should all be regarded as typical chemical phenomena. The object of this paper is largely to show that *chemical knowledge already available* is directly applicable to the study of these phenomena.

6. From a consideration of such properties as specific heat, compressibility, coefficient of expansion, etc., it is concluded that collisions do not take place between the atoms of solids, but that these move about equilibrium positions under the influence of both attractive and repulsive forces.

7. The "time of relaxation" of the atoms of solids is calculated approximately from the heat conductivity and is found to be of the order of 10^{-14} to 10^{-7} seconds. An independent method by which the "time of relaxation" can be calculated from the rate of evaporation of a substance in vacuum gives substantially similar results. Thus the time necessary for an atom of a solid to reach thermal equilibrium with its neighbors is very small compared to the time necessary to make a single oscillation about an equilibrium position. The "oscillations" are thus extremely strongly damped.

8. Since solid substances in general are held together by secondary rather than primary valence, there are few limitations to the number of compounds that can exist in the solid state. Most of these compounds do not show a composition which could be predicted from the ordinary rules of valence. Metallic compounds, minerals, solid solutions and glasses are discussed from this point of view.

9. By considerations based largely on the compressibility, it is concluded that the attractive forces between atoms usually reach a maximum intensity when the distance between adjacent atoms in solids is increased by about 0.6×10^{-8} cm. (10–30 per cent. of the normal distance between atoms).

10. Since energy must be expended in breaking apart a solid, the surface of solids must contain more potential energy than do the corresponding number of atoms in the interior. Since this potential energy is probably electromagnetic energy in the field between atoms, the interatomic forces are more intense on the surface than in the interior. This intense field of force (unsaturated chemical affinity) is one of the causes of the phenomena of condensation and adsorption.

11. Because of the small time of relaxation and because an atom approaching the surface is attracted by many, but later is repelled by few atoms, it follows that the surfaces of solids are almost wholly inelastic in regard to collisions of molecules impinging on the surface. There is also a great deal of experimental evidence of this inelasticity. As a result, nearly every molecule or atom striking a solid surface condenses, no matter what the temperature may be. While condensed it is held to the surface by forces quite similar to those holding solids together (either primary or secondary valence). At high temperatures evaporation may take place almost immediately after condensation, but at lower temperatures, the condensed atom or molecule may remain indefinitely.

12. The phenomena of condensation and evaporation (sublimation) of solids are discussed at some length. In general, the rate of evaporation (m) of a substance in a high vacuum is related to the pressure (p) of the saturated vapor by the equation

$$m=\sqrt{\frac{M}{2\pi RT}}p.$$

Red phosphorus and some other substances probably form exceptions to this rule.

13. The mechanism of the dissociation of a solid, such as $CaCO_3$, is discussed. It is shown that when, according to the phase rule, separate phases of constant composition are present, the reaction must take place exclusively at the boundaries of these phases. This kinetic interpretation of the phase rule indicates

clearly the distinction between reactions in which solid solutions are formed and those in which separate phases appear. This theory offers a ready explanation for the fact that hydrated crystals frequently fail to effloresce unless scratched and for the fact that thoroughly dehydrated substances often absorb moisture with great difficulty.

14. Adsorption is a direct consequence of the time lag between the condensation and the subsequent evaporation of molecules. The adsorbed substance may be held to the surface either by secondary or primary valence. In either case it is profitable to regard the phenomena as chemical in nature. A large number of experimental results are given which prove conclusively that adsorption is very frequently the result of the strongest kind of chemical union (primary valence) between the atoms of the adsorbed substance and the atoms of the solid.

15. It is shown that the action of a typical catalytic poison depends on the formation of a very stable film one atom deep over the surface of the catalyzer. The chemical activity of any solid surface depends upon the nature of, the arrangement of, and the spacing of the *atoms* forming the surface layer. There is a very close relation between the chemical activity of a surface and the electron emission from it (either thermionic or photoelectric emission).

16. A brief quantitative development of this theory of heterogeneous reactions is given. A " law of surface action " analogous to, but different from, the " law of mass action " is proposed. This theory is in accord with and affords an explanation of Reichinstein's " Constant Sum Hypothesis." An outline is given of the application of this theory to heterogeneous gas reactions and to enzyme action.

The second part of this paper will deal with the Structure of Liquids with particular reference to surface tension phenomenon. It will be shown that the surface tension of organic fluids is a characteristic *chemical* phenomenon. It depends particularly upon the *shapes* of the group molecules and upon the relative intensities of the chemical activity of different portions of the molecules. A method will be described (together with experimental data) by which the *cross sections, lengths* and other dimensions of the group molecules of liquids may be determined.

Arch Centers Suspended from Old Plate Girders. ANON. (*Engineering News*, vol. 76, No. 18. November 2, 1916.)—In the construction of a reinforced-concrete arch bridge crossing over the Lackawanna R. R. at Millburn, N. J., the right-of-way was kept clear of falsework by suspending the arch forms from plate girders spanning the abutments. This part of the line is subject to very congested commuting traffic in morning and evening on all three of the tracks, so that it was highly desirable that the usual falsework posts be omitted. Rather than use steel arch centers (which would reduce the top clearance to dangerous limits) or attempt to space falsework posts for clearance, the engineers decided to suspend the forms from above, utilizing an abandoned plate-girder bridge that could readily be brought to the site.

The arch is on a skew with a single rib carrying an earth fill between gravity spandrel walls. The abutments and the arch were constructed first, the arch being carried up to the limit of its overhang on segmental forms supported from struts well outside the outer tracks. The arch rib was finished here with jogged skewbacks normal to the time of thrust. The intervening section, 45 feet span, was carried by the suspended centering. On the abutments were then placed four plate girders. Each girder was about 60 feet long and 6 feet deep. The centering consisted of 3 x 3 inch angles shaped to the arch curve carrying 2 x 2 inch transverse lagging supported by ¾ inch rods. The suspender rods were covered with tubing so that they could be readily removed when the arch concrete had reached a proper set. The proper curve could be readily controlled by screws at the top of the rods. The method proved very successful, and more economical than using the steel ribs embedded in concrete, considering the high cost of such steel at the time this work was done.

Use of Diatomaceous Earth in Sugar Refining. ANON. (*U. S. Geological Survey Press Bulletin* No. 297, November, 1916.)—Diatomaceous earth, which is made up of remains of minute aquatic plants, is a light earthy material resembling chalk or clay. The hardness, the minute size, and the angular shape of its grains make it an excellent metal-polishing agent, and heretofore it has been largely used as an abrasive in the form of polishing powders and scouring soaps. Of late, however, according to the United States Geological Survey, Department of the Interior, the uses of diatomaceous earth have been considerably extended. It is used by sugar refiners for filtering or clarifying; as an insulating packing material for safes, steam pipes and boilers; and as a fireproof building material. In the United States it is used in the manufacture of records for talking machines. In Europe it has been used in preparing artificial fertilizers and in the manufacture of water glass, cements, artificial stone, paper, sealing wax, fireworks, papier-mâché, and other articles. A total of 4,593 tons of diatomaceous earth was produced and sold in the United States in 1915.

THE FRANKLIN INSTITUTE

(*Proceedings of the Stated Meeting held Wednesday, December* 20, 1916.)

Hall of The Franklin Institute,
Philadelphia, December 20, 1916.

President Dr. Walton Clark *in the Chair.*

Additions to membership since last report, 8.

Mr. Charles E. Bonine, Chairman of the Committee on Science and the Arts, reported the condition of the work of the Committee.

The following nominations were made for officers and managers to be voted for at the annual election to be held on January 17, 1917:

For President (to serve one year), Walton Clark.

For Vice-President (to serve three years), Coleman Sellers, Jr.

For Treasurer (to serve one year), Cyrus Borgner.

For Managers (to serve three years), G. H. Clamer, Theobald F. Clark, Walton Forstall, Benjamin Franklin, Harry F. Keller, Richard Waln Meirs, George D. Rosengarten, William Chattin Wetherill; (to serve two years), Nathan Hayward.

The Chairman appointed the following members to act as tellers of the election: Messrs. W. N. Jennings, Henry F. Colvin, and Lucien E. Picolet.

The paper of the evening was presented by Mr. Leo Wallerstein of the Wallerstein Laboratories, New York City, entitled, "Enzymes in the Fermentation Industries." A brief outline was given of the nature of enzymes, their physical and chemical properties, their classification, commercial properties, and modes of action. The various manufacturing operations in the fermentation industries, including malting, brewing, and vinegar making, were described, and their dependence on enzymatic action was considered. It was shown how the quality of the finished product depends to a large extent on the various enzymatic actions which take place during malting, mashing, and fermentation. The speaker also described his method of employing proteolytic enzymes for rendering beers chillproof and stable. The subject was illustrated by experiments, specimens, lantern slides, and diagrams.

After a vote of thanks to the speaker, the meeting adjourned.

R. B. Owens,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(*Abstract of Proceedings of the Stated Meeting held Wednesday, December* 6, 1916.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, December 6, 1916.

MR. C. E. BONINE *in the Chair.*

The following reports were presented for first reading:

No. 2682.—The Hooven Automatic Typewriter.

Representatives of the Hooven, Owens, Rentschler Company appeared before the Committee and explained the operation of the Automatic Typewriter.

No. 2684.—The Schoop Metal Spraying Process.

A representative of The Metals Coating Company of America appeared before the Committee and showed samples of various substances that had been coated by this process.

R. B. OWENS,
Secretary.

SECTIONS.

Electrical Section.—A joint meeting of the Section and of the Philadelphia Section of the American Institute of Electrical Engineers was held in the Hall of the Institute on Thursday, November 23, 1916, at 8 P.M.

Mr. Paul Spencer and Mr. H. P. Liversidge presided jointly.

Dr. John B. Whitehead, Professor of Electrical Engineering, Johns Hopkins University, Baltimore, Maryland. delivered a lecture entitled "The Electric Strength of Air and Methods of Measuring High Voltage." Electrical Engineers are chiefly interested in the air as an insulator. Present theories of the electric properties of the air have been developed with experiments at low pressure as a basis. Many observations at atmospheric pressure have not been completely identified with existing theories. Townsend's theory of ionization by collision, and its relation to the laws of the electric strength of air at atmospheric pressure, as based on recent experiments with alternating and continuous potentials, was briefly reviewed in the lecture. Reference was also made to present methods of measuring high potentials. Recent experiments, showing how the electric properties of the air may be used as a standard method of measurement of high voltage, were described.

After a discussion of the paper by Mr. Charles Penrose, Dr. Carl Hering, and others, a rising vote of thanks was extended to the speaker and the meeting adjourned.

T. R. PARRISH,
Acting-Secretary.

Section of Physics and Chemistry.—A stated meeting of the Section was held in the Hall of the Institute on Thursday, December 7, 1916, at 8 o'clock P.M. with Dr. Gellert Alleman in the chair.

G. A. Burrell, chemist in charge of the Laboratory for Gas Investigations in the Experimental Station of the Bureau of Mines, U. S. Department of the Interior delivered an address on "The Extraction of Gasoline from Natural Gas."

The two processes for the extraction of gasoline from natural gas on a commercial scale were described: (1) The condensation of the gasoline by subjection of "casinghead" gas to high pressures and cooling with water at atmospheric temperature, and (2) the absorption of gasoline from "dry" gas in a prepared petroleum oil, followed by distillation with steam, and recovery of the gasoline in the distillate. The history, the underlying physico-chemical principles, the essential installations of machinery, the mode of marketing, and the characteristics of the product were outlined for each process. Statistics were given concerning the quantity of gasoline extracted from natural gas under commercial conditions. The methods for determining the gasoline content of a natural gas were described. The lecture was illustrated with lantern slides. After a discussion of the paper, a vote of thanks was extended to Mr. Burrell, and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

Mechanical and Engineering Section.—A joint meeting of the Section and the American Society of Mechanical Engineers was held in the Hall of the Institute on Thursday, December 14, 1916, at 8 P.M.

Mr. George R. Henderson, President of the Section, and Professor Fernald presided jointly.

Mr. Henderson introduced C. C. Thomas, M.E., Professor of Mechanical Engineering, Johns Hopkins University, Baltimore, Maryland, who delivered an illustrated lecture entitled: "The Cooling of Water for Power Plant Purposes."

Professor Thomas briefly reviewed the methods of cooling water and made special reference to efficiencies obtained particularly with respect to Spray Ponds. He also described a new form of Spray Head and reported upon tests made under widely varied conditions. Factors affecting the efficiencies in Spray Ponds were discussed. The paper was a report of progress rather than a completed investigation.

After an interesting discussion a vote of thanks was extended to the speaker. Adjourned.

T. R. PARRISH,
Acting-Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(*Stated Meeting, Board of Managers, December* 13, 1916.)

RESIDENT.

MR. HENRY B. COWAN, District Engineer, The Bell Telephone Company of Pennsylvania, and for mail, 502 North 39th Street, Philadelphia, Pa.

MR. P. T. DASHIELL, Engineer, The United Gas Improvement Company, Broad and Arch Streets, Philadelphia, Pa.

MR. FREDERICK C. FEARING, Consulting Engineer, 1088 Drexel Building, Philadelphia, Pa.

MR. F. T. GUCKER, Civil Engineer, 1025 Witherspoon Building, Philadelphia, Pa.

DR. R. W. RUPRECHT, Chemist, 15 North 5th Street, Philadelphia, Pa.

MR. JOHN C. TRAUTWINE, 3d., Civil Engineer, 257 South 4th Street, Philadelphia, Pa.

NON-RESIDENT.

DR. E. G. LOVE, Chemist, 130 East 15th Street, New York, N. Y.

MR. EARL DILLMON MILLS, Metallurgist and Chemist, The Buda Company, Harvey, Illinois.

CHANGES OF ADDRESS.

MR. ROBERT J. ANDERSON, 10839 Pasadena Ave., Cleveland, Ohio.

MR. LEONARD W. COLEMAN, 716-17 Witherspoon Building, Philadelphia, Pa.

MR. MORRIS EBERT, 1706 Green Street, Philadelphia, Pa.

MR. ERNEST JOHANSEN, 439 South 51st Street, Philadelphia, Pa.

MR. MORTON G. LLOYD, 1040 Ontario Street, Oak Park, Ill.

COL. SAMUEL REBER, War Department, Federal Building, Chicago, Ill.

DR. WALTER F. RITTMAN, Fitzsimmons Building, Pittsburgh, Pa.

MR. MELVIN L. SEVERY, 431 South Berendo Street, Los Angeles, Cal.

MR. H. CLYDE SNOOK, 224 Linden Avenue, Oak Park, Ill.

MR. THOMAS SPENCER, 1628 Alameda Street, Lakewood, Cleveland, Ohio.

MR. HENRY R. TOWNE, 420 Park Avenue, New York, N. Y.

NECROLOGY.

Mr. Joshua L. Baily was born at Philadelphia on June 27, 1826, and died at Ardmore, Pennsylvania, on December 6, 1916.

When sixteen years of age Mr. Baily entered the dry goods business in which he continued throughout his life. At the time of his death he was the senior member of the firm of Joshua L. Baily & Company of Philadelphia and New York.

Mr. Baily was intensely interested in many civic affairs and was an active member of a number of charitable organizations.

He became a member of The Franklin Institute on March 4, 1892.

Mr. Charles Alfred Rutter was born in Philadelphia, October 30, 1857, and died at Holly Oak, Delaware, August 3, 1916. He was educated at Rugby Academy, and at the University of Pennsylvania, receiving the degree of Mechanical Engineer from the latter Institution in 1878.

Soon after his graduation he began his professional career as a solicitor of patents, and continued in this field to the time of his death. During the last four years of his life Mr. Rutter was also President of the Essington Ship Building Company, Limited.

While very mechanical in his tastes, Mr. Rutter was catholic in his reading and studies, and possessed a varied fund of useful information. He formed an excellent ethnological collection, the principal articles of which illustrated the life of the Lenni Lenape Indians. His main diversion was yachting, and in the handling of the yacht he was a master. He had a thorough knowledge of the Delaware and Chesapeake Bays.

Mr. Rutter was a member of the Second Regiment of the National Guard of Pennsylvania, and served in the Spanish War. He was also a member of the Historical Society of Pennsylvania, The University Club, and other organizations. He became a member of The Franklin Institute on March 6, 1880, and served on its Committee on Science and the Arts from 1887 to 1891, and in 1903.

Mr. William Bell Wait was born at Amsterdam, N. Y., on March 25, 1839, and died in New York City on October 25, 1916.

He was educated in the public schools of Albany, N. Y., the Albany Academy and the Albany Normal College.

In 1859 he became a teacher in the New York Institute for the Education of the Blind. Later he studied law and was admitted to the bar in 1862. In October, 1863, he was made emeritus principal of the Institute for the Education of the Blind, which position he held until the time of his death.

He devised the New York point system for the use of the blind and also developed a system of tangible musical notation.

In 1894 Mr. Wait invented the kleidograph, a machine for embossing in the New York Point system on paper, a typewriter for the blind, and later a machine for embossing metal plates to be used in printing books for the blind. For these inventions he was awarded the John Scott Medal by the city of Philadelphia on the recommendation of the Franklin Institute.

The patents for all his inventions were dedicated by him to the public to be used in the amelioration of the conditions of the blind.

Mr. Wait was the author of the following works: The Normal Course of Piano Technic (1888); Harmonic Notation (1888); Phrases of Punctography (1913); The Uniform Type Question (1915); and The Aspects of the Uniform Type Folly (1916).

He became a member of The Franklin Institute on March 27, 1902.

Lt. Col. Theo. Turrettini, Geneva, Switzerland.

Dr. Martin I. Wilbert, Hygienic Laboratory, 25th and E Streets, Washington, D. C.

Mr. Thomas L. Willson, Ottawa, Ontario, Canada.

LIBRARY NOTES.

PURCHASES.

BACON, R. F., and Hamor, W. A.—The American Petroleum Industry. 2 vols. 1916.

BRUNNER, Richard.—Manufacture of Lubricants, Shoe Polishes and Leather Dressings. 1916.

CUNNINGHAM, E.—Relativity and the Electron Theory. 1915.

EDWARDS, C. A.—The Physico-Chemical Properties of Steel. 1916.

GOETHALS, GEO. W.—The Panama Canal, an Engineering Treatise. 2 vols. 1916.

GOOD ROADS YEAR BOOK.—Fifth Annual Issue. 1916.
HEATH, G. L.—The Analysis of Copper, and Its Ores and Alloys. 1916.
KAPP, GISBERT.—Principles of Electrical Engineering and Their Application. Vol. 1. 1916.
MIESSNER, B. F.—Radiodynamics, the Wireless Control of Torpedoes. 1916.
MITCHELL, W. A.—Vinegar, Its Manufacture and Examination. 1916.
ROSE, SIR T. K.—The Metallurgy of Gold. 1915.
ROWLAND, A. J.—Applied Electricity for Practical Men. 1916.
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ORGANIC CHEMISTRY FOR THE LABORATORY, by W. A. Noyes, Easton, Pa., The Chemical Publishing Company, 1916, 291 pages, illustrations, 8vo, price $2.00.

This is an excellent laboratory manual of organic chemistry. The material offered is extensive—one hundred and thirty-two preparations, which partly accounts for the unusual size of the book. Among these are several which show that the more recent developments have not escaped notice, *e.g.*, one involving the Barbier-Grignard synthesis (p. 73) and the preparation of cyclo-hexane by the catalytic reduction of Sabatier (p. 50). The preparation of zinc-ethyl (p. 61) might well have been omitted. It is dangerous even in moderately skilled hands, and, as a synthetic reagent, zinc-ethyl is, to all intents and purposes, obsolete.

The references to the original literature are remarkably complete and interesting. In the hands of the rare student who desires to use them and who has the necessary linguistic equipment they will be of great value. The reviewer notes with pleasure an uncommon feature in a laboratory manual—the presence of an excellent index. The book is well printed and substantially bound.

ROBERT H. BRADBURY.

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CURRENT TOPICS.

Life of Ammonia Pump Rods. D. L. FAGNAN. (*Power,* vol. 44, No. 20. November 14, 1916.)—As is generally known, the life of the piston rods of ammonia pumps in refrigerating plants is comparatively short, and the rods must be packed quite frequently to prevent leakage of ammonia. The frequent packing wears the rod considerably, and many engineers keep on hand several sizes of packing rings. Keeping on hand several sizes of packing rings and repacking the rod every two or three weeks is a source of loss of ammonia. Inquiries of 230 operators in one year showed that 25 had to renew the rod every three months and to repack it every three weeks. This experience of the operators was corroborated by reports from various ammonia pump manufacturers.

Experiments with materials for pump rods showed that the best service is given by a high grade tool steel. This rod was packed with fibrous packing symmetrically arranged about a central metallic insertion. The rod has been in service for more than a year, running 18 hours a day in summer and 6 to 8 hours a day in winter, and the wear is only 0.002 inch. From five to six drops of oil per minute is fed over the rod, and it is only upon starting, during the first few strokes, that the odor of ammonia is perceptible.

Frequency Standardization. ANON. (*Power,* vol. 44, No. 20, November 14, 1916.)—The first alternating-current system operated at 133 or 125 cycles, single-phase. This seemed to be the correct practice for the generators and transformers used at that time, as this type of apparatus was less expensive to construct than the lower-frequency equipment. In some cases a frequency of 116 cycles was used. With the development of the polyphase system, it was found desirable to use a lower frequency, consequently the sixty-cycle system was adopted. As the transmission voltage was increased, it was again found desirable to decrease the frequency, and 25 cycles found its place in the category of alternating-current systems. This frequency had several advantages, among them low charging current in high-voltage transmission lines and its adaptability for synchronous converters and series railway motors. In the case of the synchronous converter, however, this advantage has almost disappeared, as in late years the sixty-cycle converter has become a successful apparatus. For various reasons there have been a number of other frequencies adopted, such as 66.6, 62.5, 50, 40, 38 and 30 cycles. These are some that we find in our own country. Turning attention to Europe, we find in addition such frequencies as 100, 83, 42, 33 and even 15 cycles, the last being used for railway work.

When it is taken into consideration that many of these systems operating at one frequency cannot be coupled to other systems operating at a different frequency and that, when it is possible, expensive and inefficient machines are required, the necessity for standardizing the frequencies at once becomes apparent. The question of what should be the standard frequency is one that is not definitely settled. In the western part of the country, preference is given to the sixty-cycle system; in the East, the twenty-five cycle is looked upon as preferable. Outside of the fact that twenty-five cycle systems have been installed to a very large extent, and had various advantages at the time they were adopted, there exists at the present time no reason for their continuance except for single-phase railway work. In almost every other case the sixty-cycle system has distinct advantages over systems operating at any other frequency. Therefore, it seems that, when the industry is relieved of this conglomeration of frequencies by the adoption of some standard, the day will be hastened when electricity will be used universally for the transmission of energy.

Multiple Telegraphy System Based on the Attunement of Frequency. ANON. (*Scientific American,* vol. cxl, No. 20, November 11, 1916.)—In Europe there has been recently developed a system of telegraphy which makes it possible for any station to communicate with any other station on the same line without disturbing in the slightest degree the remaining stations. In the new system the receiving instrument of a given station is affected only by an alternating current of given frequency, while its transmitting apparatus is capable of generating any of the frequencies necessary to be received at any of the stations. It is said that the best practice is to employ frequencies between 600 and 1100 per second. It is necessary to avoid employing frequencies of which one is an exact multiple of the other; and the increments between successive frequencies cannot be less than 40 with certainty of reception. Hence without exceeding the limits, 600 to 1100, it is impossible to include more than 14 stations on a line.

In essential principle the receiving instrument consists of a telephone receiver with a steel membrane supported at three nodal points so that it will vibrate distinctly only in response to a current of frequency corresponding to its diameter. Messages may be received by the use of a relay of mono-frequency in combination with a differential relay.

Forced Life Tests of Incandescent Lamps. L. J. LEWINSON. (*Transactions of the Illuminating Engineering Society,* vol. xi, No. 8, November 20, 1916.)—Forced tests of incandescent lamps have been devised primarily for the purpose of surmounting to some extent the obstacle of delay in securing results, which is inherent in normal life tests of lamps operated at or near their labeled voltage. Incidentally the cost of testing is reduced, principally because of the decrease in energy consumption.

Methods of making forced tests differ somewhat among various laboratories engaged in this kind of work. In one of these, the lamps are measured to determine the voltage at some stated watts per candle. The voltage obtained is then multiplied by a constant factor to determine the forced test voltage. For example, a forced test voltage in common use has been 130 per cent. of the voltage at which tungsten lamps consume 1.23 watts per candle. The equation most conveniently used is:

$$\frac{L_1}{L_2} = \left(\frac{\omega pc_1}{\omega pc_2}\right)^b$$

where L_1 and ωpc_1 and L_2 and ωpc_2 are respectively the normal and the forced values of the life and watts per candle, and b a variable exponent. While little authoritative data are available showing the variation of this exponent, there is evidence that the use of a constant exponent over a limited range will yield results which are not subject to considerable error. A forced test however has little value unless proper means of interpretation are at hand, and correction factors determined under one set of conditions must not be applied under other conditions unless their applicability has been proved.

The Future of Forts. H. BERTHAUT. (*The Engineer,* vol. cxxii, No. 3176, November 10, 1916.)—A considerable amount of discussion has been taking place as to the value of permanent fortifications. Certain writers have dwelt on the fact that, in the present war, many fortresses have offered an inadequate resistance or none at all, in order to prove that permanent fortification is a thing of the past, being no longer suited to play any useful part. The logical outcome of this view would be to insist on the abandonment and demolition of all fortresses. We must realize that the science of fortification has not reached finality any more than other sciences. At any particular time it conforms to certain conditions, and these keep on changing. In recent years so rapid have been the advances in the construction of cannons and in the force of explosives, that the science of fortification has been outdistanced.

If fortresses have not proved to be as strong as is essential, that is not the real reason why some of them have offered so brief a resistance; it is rather because, as compared with the attacking forces, their artillery was insufficient and they had an inadequate supply of shells. Make the defending batteries as strong as those that attack, make the conditions equally favorable, and they will certainly prove superior, since they have the advantage of being able to choose the most favorable positions for the guns, and of being better and more solidly constructed. The objection may be raised that the attacking force is fully aware in advance of the exact place occupied by the object to be attained, while the defense has to ascertain where the attacking batteries are before being able to counter attack. That is so; but it has always been the case, and it is of less importance now than formerly, since aviation affords a very rapid means of locating an attacking battery; and the possibilities of aviation are far from being exhausted.

No indication can be attempted here how fortresses should be constructed, to sketch their elevations and ground plan. That requires long and elaborate study. It has, however, been shown to be possible, in active warfare, to construct effective shelters for troops and solid batteries, with firm platforms for very heavy guns of great calibre, which fire projectiles of enormous weight and shake the substructure very powerfully. It has been shown by experience that these formidable machines, in spite of their weight and bulk, can be moved about, being transported either on rails or even on ordinary roads by means of traction engines. All that can be done in this way in the course of operations, on ground not specially selected and not prepared, can be still better done on foundations chosen and prepared in peace time, on roads and lines laid for this purpose, by employing all such resources as are not available on the field of battle and without exposure to danger. It is therefore possible to render the defense at least as strong as the attack, if not superior to it, by furnishing it with artillery at least equally formidable and by perfecting the installation and the mobility of this material. Permanent fortification must keep on developing: it must be transformed, not abolished. As long as there is progress in the means of attack, the means of defense will likewise progress; it must come about and it can be achieved.

Drinking Water Systems. (Publicity Department, Armstrong Cork Company, Pittsburgh, Pa.)—Legislative enactments, and a growing appreciation of the physical and economic advantages of furnishing a bountiful supply of pure water to workers in all lines of industry, have made the drinking water problem a live issue in almost every industrial establishment. The old bucket-and-dipper method is not only unsanitary, expensive and wasteful of time, but has proven positively injurious on account of the temptation to drink excess quantities at the infrequent opportunities it affords. Many plans have been tried to supply properly cooled pure water to workmen at reasonable cost: buckets of water carried from one point to another, stationary coolers, pipe lines without artificial cooling; more recently, sanitary drinking fountains with water supply cooled by separate ice boxes maintained in conjunction with each fountain. All these methods, however, fail in one or more respects to meet the requirements. Accordingly, plant owners and superintendents have been compelled to look further for the solution of the problem.

In a number of instances, the problem has been solved with remarkable success by the installation of a small refrigerating plant, water cooling tank, insulated distributing lines—with drinking fountains located at convenient points—at a total outlay of less than the operating cost for two years with the old bucket-and-dipper method. There is no economy in the employment of this method despite its seeming simplicity. A steel mill in the Pittsburgh district had been furnishing drinking water in this manner to approximately 1000 men at an annual cost of $5,000. By installing a refrigerated drinking water system at a total expense of $9,000, a permanent method of distribution was secured at a much lower operating cost. The total operating cost when the mill is working full time is $1.82 per employee per year, as against approximately $5.00 by the old method. Besides the marked saving, a material benefit is derived through increased efficiency and reduction in time lost from productive work.

The Elastic Properties of Phosphor-Bronze Wires. A. J. OEHLER. (*Physical Review,* vol. viii, No. 5, November, 1916.)—Studies on platinum-iridium wires used as suspensions for torsion pendulums have shown some remarkable elastic properties of that alloy. The principal one of these was the variation of the period of vibration with the amplitude. It was these studies that made it seem desirable to investigate other alloys for the same properties, and, because of the extensive use of phosphor-bronze wires as delicate suspensions, experiments to that end were made on that alloy.

The experiments showed that there were three distinct states, from one of which to another the wire would change, observable by a distinct change in the law of variation of period of vibration and amplitude. It was found that each state was quite stable in itself unless the wires were subjected to vigorous treatment, such as long continued vibration and long continued annealing. While these peculiarities may be typical of this alloy alone, it is very probable that all alloys have their distinct peculiarities, just as platinum-iridium wires and phosphor-bronze wires have been found to have. The results of the tests indicate that phosphor-bronze wires are not desirable as delicate suspensions, in many cases when they are used. It thus seems desirable that a careful study be made of their crystal structure with the resulting elastic constants, and from the standpoint of their practical uses.

Electric Melting of Non-Ferrous Metals. A. STANSFIELD. (*Brass World,* vol. xii, No. 11, November, 1916.)—The electric melting of non-ferrous metals has not been practised to any great extent, but offers many advantages and will no doubt attain to some importance in the near future. Both arc and resistance furnaces have been used for this purpose. Non-ferrous metals and alloys, such as copper, brass, tungsten, nickel or German silver, can be melted very conveniently, and with little loss, in crucibles placed in carbon resistor furnaces, such as the Hoskins furnace which employs resistor plates, or the Hilberger furnace in which the crucible itself is made the resistor. The use of the Hilberger furnace for brass melting is said to be inconvenient and expensive on account of the short life of the crucible. The Hering furnace, also, operates on the resistance principle, but in this case the metal itself is the resistor, and this introduces difficulties with metals like copper which have high electrical conductivity. The induction furnace, also, can only have a limited application to the melting of non-ferrous metals on account of their usually high electrical conductivity.

G. H. Clamer and Carl Hering have described very fully the use of the Hering "pinch effect" furnace for melting brass. The power consumption, when melting light brass or bronze chips, was found to be 250 kilowatt-hours per short ton of brass melted. This furnace was to be introduced at the foundry of the Ajax Metal Company in Philadelphia. H. M. St. John has given information with regard to the electric melting of brass. Two types of electrical resistance were employed—the "crucible lift out" type and the tilting type. With the tilting furnace, 280 kilowatt-hours are needed per ton of yellow brass, and 350 kilowatt-hours per ton of red brass, in continuous melting. If the power is only used for ten hours daily, the power consumption will be 400 to 500 kilowatt-hours respectively. With the crucible lift-out furnace, the power consumption is 43 per cent. more than the foregoing figures.

For the economical melting of copper, brass and other metals and alloys, the arc furnace appears to be the most efficient, but in arc furnaces there may be a serious loss by volatilization of metals like zinc, tin, and even copper, while the temperature is far less easily controlled than in the case of resistance furnaces. Messrs. Lyon and Keeney review the furnaces available for the electrical melting of copper and conclude that the Heroult steel furnace is the most suitable. The writer has had some experience with the Rennerfelt arc furnace, and considers this perhaps the most promising type of arc furnace for melting copper, brass and the non-ferrous metals generally. The Rennerfelt furnace has three graphite electrodes, one vertical and two horizontal, which meet in the middle of the furnace. These are supplied with two-phase current, the vertical electrode being the common return for the other two. This furnace, like Stessano's, has the advantage of an arc that is independent of the material to be melted, but the efficiency is better in this case owing to the downward direction of the flame.

Gasoline From Oil Shales. ANON. (*U. S. Geological Survey Press Bulletin,* No. 300, December, 1916.)—In anticipation of the day when, on account of the advancing cost of gasoline and other products obtained from petroleum, it might be found commercially profitable to utilize some of the enormous supply of petroleum to be derived from the distillation of the vast deposits of so-called hydrocarbon shales of the Green River formation of northwestern Colorado and northeastern Utah, the United States Geological Survey has for three years been making field investigations of these deposits. The examinations have been accompanied by mapping of the areas of hydrocarbon shales and by such field measurements of the thickness of the shales in workable beds and such rude field distillation tests as will afford primary information concerning the amount and richness of the shale in different parts of the region.

Very rough but cautious calculations of the contents of the shale in parts of the area examined indicate that the distillation of shale from beds over 3 feet thick in Colorado alone will yield more than 20,000,000,000 barrels of crude oil, from which more than 2,000,000,000 barrels of gasoline can be extracted by ordinary methods. A report giving the results of these explorations and tests and an account of experiments as to possible gasoline production, both by the ordinary commercial processes and by the Rittman process, are now in press.

Close-Plating. C. H. POLAND. (*Metal Record and Electroplater,* vol. ii, No. 11, November, 1916.)—Close-plating, an art practised for centuries, is carried on now to a very limited extent, and will soon be classed as one of the "lost arts." Till recent times it was regarded as one of the most important industries but it has gone down before the advance of electroplating. A few score years ago close-plating was the only method by which an article could be given the appearance of the precious metals, as all articles plated with either gold or silver were plated by this process. The massive door knobs, name plates, escutcheons, ornaments and tableware found in colonial houses, that were not of solid gold or silver, were all close-plated.

The process consists essentially in soldering on a carefully finished and tinned piece a thin sheet of soft silver shaped to fit the work. The silver sheet is stretched and worked into the crevices until it fits the part closely and then soldered. All these operations are performed with the simplest tools, but consummate skill and rare judgment are essential in the practice of the process.

Electrolytic Cleaning of Silverware. ANON. (*Metal Record and Electroplater,* vol. xi, No. 11, November, 1916.)—A bulletin recently published by the United States Department of Agriculture deals with the electrolytic method of cleaning tarnished silver, which is recommended as an easy and effective way of performing this task. It consists in boiling the article in a soda and salt solution in contact with a clean piece of aluminum or zinc. Experiments made under the direction of the Bureau showed that when silver spoons were polished with whiting paste, nearly 0.01 grain of silver each was lost, whereas with the electrolytic process, only one-twenty-fifth of this amount was wasted.

The tarnish which occurs in silver is not due to oxidation, but to the action of sulphur. The electrolytic cleaning depends upon the slight solubility of the silver sulphide in the hot solutions employed, its breaking down chemically, and the redeposition on the ware of the silver content when the proper electrical conditions prevail. The presence of both the silver and aluminum or zinc in the hot solution provides the necessary electrical conditions, practically all the silver in the tarnish being returned to the object cleaned. When the silver polishes are used, on the other hand, all the silver in combination in the tarnish is removed. Aluminum is much more satisfactory than zinc for use in this cleaning process, since it does not become coated with a layer of carbonates which could interfere with the chemical reaction. Zinc does form carbonates and if used, must be cleaned frequently in dilute hydrochloric acid. The method is most effective if the solution boils during the cleaning process, and efficiency is rapidly lowered as the temperature of the solution falls below the boiling point.

The Frequent Bursting of Hot Water Pipes in Household Plumbing Systems. F. C. BROWN. (*The Physical Review,* vol. vii, No. 5, November, 1916.)—It seems to have been a common observation by plumbers that the pipes carrying the hot water in a domestic water supply system burst from freezing more frequently than do the pipes carrying the cold water. It is said that the ratio of frequency is at least four to one. The cold water usually freezes so as to lessen the flow of water in the pipes or to stop it entirely, but this freezing is seldom accompanied by bursting. To verify the observations of the plumbers and then to ascertain the physical explanation, experiments were conducted upon a system of glass test-tubes, closed at one end and arranged to approach the conditions found in the ordinary domestic water supply system.

Ordinary tap water freshly drawn was placed in the tube to simulate the conditions in the cold-water pipes. The same tap water, shortly after being boiled, was placed in like tubes to simulate conditions in the hot-water pipes. The tubes were placed in the open air when the outdoor temperatures were at varying degrees below zero. On seven occasions about 50 pairs of tubes were tried, and in every test the tubes of boiled water broke first. When the observations were concluded it was noted that 44 tubes containing boiled water had burst and only four of those containing unboiled water had broken, thus verifying the observations of plumbers.

It was found that the boiled water was invariably undercooled several degrees below zero before freezing commenced and that, after crystallization began, the temperature remained at zero until the entire mass was frozen. The ice was quite clear and solid. The unboiled water always began freezing at zero, and the ice was full of air bubbles and appeared quite slushy, particularly near the central axis of the tube. These air bubbles together with the accompanying impurities form nuclei for crystallization and also act as cushions to react against the expansion of the water by freezing. The air also tends to freeze out toward the middle, and this semi-open center acts as a safety valve to relieve the pressure caused by freezing. The under-cooling of the air-free water tends to make the center of the tube freeze just as solid as the water near the surface of the tube. Although ordinary tap water freezes more readily than the boiled water, it does not freeze solid, while the boiled water with its freedom from air freezes solid and exerts a greater bursting pressure.

Power Generation by Volcanic Heat. PROF. LUIGGI. (*Engineering,* vol. cii, No. 2655, November 17, 1916.)—In Central Tuscany, near Volterra, there are numerous cracks in the ground from which powerful jets of very hot steam spout high in the air with great violence and constancy, bringing up boric acid, which is very valuable, and other mineral substances of less importance. These powerful jets of super-heated steam are called *Soffioni*—the "blowers"—and have been utilized for many years in the production of boric acid and borax, and occasionally for warming the houses in the near-by village of Larderello. The larger proportion of the steam, however, is lost, having no local application, and with it is lost its very valuable heat.

Experiments demonstrated that each bore can provide steam at a temperature of 150° C. and at the rate of 15,000 to 25,000 kilograms per hour. Encouraged by these results, Prince Ginori-Conti, in 1906, applied the steam to an ordinary steam engine of about 40 horse-power. The experience of several years has shown that this arrangement works well, so far as the mechanical power of the steam is concerned, but that the borax salts and the gases mixed with the steam, especially sulfuric acid—have a corrosive action on the iron parts of the engine and are the cause of frequent repairs. In a later project this difficulty was overcome by driving the engine with steam from pure water generated by the ground steam in a heater. Steam was produced at a pressure of two atmospheres, then passed through a superheater, and afterwards used for driving a 300 horsepower condensing steam turbine, connected directly to a three-phase electric generator which has been supplying the works and villages around Larderello.

Stimulated by the scarcity of coal since the breaking out of the European war, and previous success, a much larger installation was projected and there are now in operation three (3000) kilowatt units supplying power to many towns of Tuscany. This very successful application of volcanic heat to power generation can be increased to practically hundreds of thousands of horse-power as the region of the Soffioni extends for many square miles around Larderello.

Photographic Color Prints on Silk Fabrics. ANON. (*Scientific American,* vol. cxv, No. 24, December 9, 1916.)—A method of printing silk fabrics by color photography, due to Messrs. Vallette and Feret of the Manufacture Nationale des Goblins, France, presents results which appear to be interesting in the sense that the process makes possible the production of silk fabrics for decorative effects, the perfection of which did not seem to have been hitherto attained in printing. The method is, of course, borrowed from color photography, and consists in making three successive impressions—blue, yellow and red—from three selected photographic plates.

The fabric is rendered sensitive by the aid of mixtures of alkaline phenols and diazo sulphites, products which possess the property of giving coloring matter only through the influence of light. The precision needed in superposing the three impressions is secured by carrying out the work on a special frame, the fabric having been previously provided with metallic eyelets to avoid tearing it. The development of the colors is accomplished with better regularity by exposure to electric light. The method is recommended by its originators as more especially applicable in the treating of articles de luxe of the sort that cannot be well printed by machine.

American Starting and Lighting Systems. A. L. CLAYDEN. *Proceedings of the Institution of Automobile Engineers.* November, 1916.)—The application of electric starting and lighting systems to American automobiles began in 1912 when the Cadillac Company adopted an outfit produced by the Dayton Engineering Laboratories Company of Dayton, Ohio. It is not suggested that the idea originated with this company, but they were the first to produce a machine to be adopted by any motor car manufacturer as standard practice. The Delco apparatus, as it is called, operated on a peculiar patented system which is still used by the Cadillac Company. Briefly it consists of an arrangement of clutches which allows a single armature to operate at comparatively low speed when being used for generating electricity and at comparatively high speed when being used for starting the internal combustion engine.

The introduction of the self-starting Cadillac created so strong a demand for automatic starting that it became obvious within a few months that every competitor would be obliged to employ similar equipment. The tendency at first was to favor the single unit machine capable of acting both as generator and motor because of simplicity, but this was restricted by the Delco patents to an invariable gear ratio between the armature and crankshaft. Such single units are still used in a few cases, and are particularly popular for equipment designed for the Ford car, because they can be produced very cheaply. Where cheapness is not the only consideration, the two-unit system has proved preferable. A comparison of the electrical characteristic of the single-unit and two-unit systems has demonstrated that the latter is the more efficient, but the greatest drawback to the single-unit is the weight of the armature and the impossibility of making satisfactory gearing for connecting it to the crankshaft.

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THE DEVELOPMENT OF THE CERAMIC INDUSTRIES IN THE UNITED STATES.*

BY

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The most ancient of the industries, that dealing with the molding and firing of clay forms, one of the last strongholds of pure empiricism, is giving way under the pressure of scientific advance and is undergoing decided changes at the present time. The first impetus towards the employment of scientific methods in the solution of ceramic problems was due principally to the work of Hermann August Seger in the late eighties, and his writings have proved the basis on which later developments have been built up. Of late the influence of physical chemistry in its several branches has made itself felt.

Clays are mixtures of usually finely-divided hydrous aluminum silicates with coarser granular matter, such as quartz, feldspar, mica, etc. There are represented all grades of subdivision, from the coarsest to the finest. The property of plasticity, the ability of the substance to be molded when admixed with water

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* Presented at the meeting of the Section of Physics and Chemistry, held Thursday, November 2, 1916.

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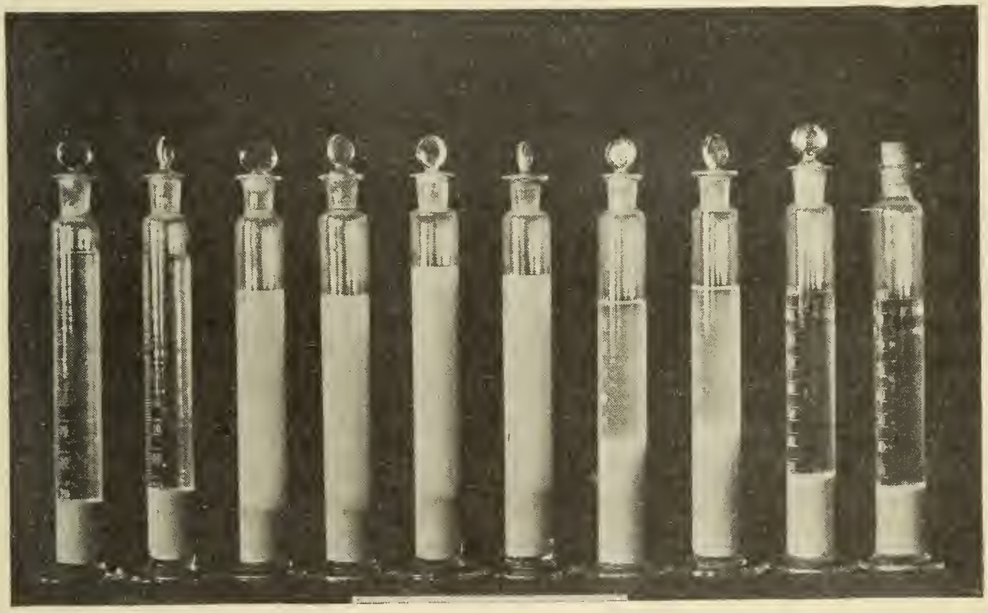
and to retain the shape imparted to it, is to be attributed to the dispersed state of the aluminum silicates known under the general term of clay substance. Indeed, a portion of the mass making up clays may be considered to possess the properties of a suspensoid colloidal system. Organic coloids and electrolytes influence the latter to a very considerable extent. The aluminum silicates, by virtue of their very complex constitution, their content of O H groups, and their slight solubility in water, are inclined to be more stable in the amorphous than in the crystalline state.

The effect of electrolytes upon clays suspended in water, as well as in the plastic state, is of a far-reaching character. Thus, alkalies, such as sodium hydroxide and sodium carbonate, tend to increase the degree of dispersion of the clay particles and to reduce the viscosity of the suspension in a decided manner. This may be readily illustrated by adding a small amount of caustic soda to a clay suspension, when it will be found that a portion of the clay will become so fine that it will pass through filter paper, a condition which did not exist before. Again, by determining the viscosity of the clay suspension by means of a simple form of flow viscosimeter, it will be found that the fluidity of the system is greatly increased by the alkali addition, frequently as much as 100 per cent., and more. The effects thus noted are evidently due to the action of the negatively charged OH ions. These repel the similarly charged clay particles electrostatically and thus they increase the state of dispersion of the system, breaking up the larger aggregates into smaller particles. The water hence penetrates more deeply into the clay structure and causes the clay to "liquefy." A clay suspension in this condition will hold up the fine particles of clay substance while the granular material, due to the decreased viscosity of the system, will settle out promptly. The maximum effect of this action, known as deflocculation, is brought about by a definite concentration of OH ions, and if this is exceeded the reverse effect will be produced, shown by increased viscosity and "stiffening." This stage may again be followed by a second drop in viscosity by adding additional amounts of alkali or by allowing the suspension to stand. In the latter case the effect is due either to adsorption of the salts or to chemical reaction with the hydrous silicate. The action is frequently complicated by the two last named phenomena.

It must be assumed that the addition of alkali produces a certain, probably very small amount of highly dispersed material approaching in its behavior the lyophile emulsoids. The portion of the clay assuming this state must, in the nature of the case, oppose the settling out of the granular material made mention of above. Hence in the separation of crystalline material from highly dispersed clay substance, it is necessary to use a much larger amount of water than with coarser clays. The phases of flocculation, deflocculation and re-flocculation occurring with increasing amounts of alkali are shown in the photograph of Fig. 1.

FIG. 1.



Deflocculation and coagulation of kaolin suspended in water.

The condition shown existed after allowing the tubes to stand for 12 hours. The material still in suspension is evidently of very great fineness, since all other particles must have settled out after so long a time. Where separation of the highly dispersed clay substance from the granular material such as quartz, feldspar, ilmenite, pyrite, biotite, mica, etc., is desired, the time of settling is of considerable importance, inasmuch as the particles are precipitated according to Stoke's law.

The deflocculated, alkaline suspension is immediately coagulated and precipitated by the addition of acids and salts, like aluminum sulphate, barium chloride, etc. The flocculating effect appears to be a function of the valency of the cation since, for instance, the salts of aluminum are very much more effective than those of calcium, and the latter more so than potassium salts.

The facts stated above are applied industrially in improving the washing process employed in the purification of kaolins and in the so-called casting process. Up to the present time the washing of the kaolin from the crude rock mixture consisted in blunging up the material with water to a thin suspension and depositing the waste rock débris by causing the liquid to flow through settling troughs into basins where the finest granular matter was separated. The fact that the addition of alkali lowers the viscosity of the clay-water system and thus brings about a sharper and more prompt separation of granular and dispersed clay matter, caused Keppeler[1] to invent a process making use of this phenomenon, thus improving the washing process by securing a purer yield of clay substance. This process was first brought to the attention of the American industries by the late H. E. Ashley, who worked out in detail the principles involved.[2] The same principle was employed also by Count Schwerin[3] in his endosmose process in which deflocculation by means of alkali is followed by the deposition of the clay substance upon a metallic band which forms the positive electrode. The negatively charged clay particles are thus deposited by the electric current, and at the same time separated from the water. It has been shown that the electrical separation has no connection with the purification of the kaolin itself, since this is accomplished by the preliminary treatment with alkaline electrolytes.[4] These methods, though simplified, have been used by the Clay Products Laboratory of the Bureau of Standards[5] in the purification of several American kaolins and in the application of the principle in a kaolin washing plant of Eastern Pennsylvania, in 1914. The Bureau of Mines has employed the process in the purification of Georgia kaolins. There is every reason to believe that by means of such processes it will be possible to treat American kaolins so that they can be utilized in the manufacture of the highest grades of porcelains.

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[1] German Patent No. 201,987.

[2] Trans. American Ceramic Society, vol. 12, p. 768, Bureau of Standards' Technologic Paper No. 23.

[3] *Tonindustrie Ztg.*, 36, 1283–85. Trans. English Ceramic Society, 12, Part I, 36–65.

[4] Trans. American Ceramic Society, vol. 15, p. 338. Bureau of Standards' Technologic Paper No. 51.

[5] Technologic Paper No. 51.

The other industrial application of the deflocculation of clays is connected with the so-called casting process in which the mixture of kaolin, ball clay, feldspar and quartz, producing porcelain, with the simultaneous introduction of a small amount, usually 0.5 per cent. of a mixture of sodium carbonate and sodium silicate is made into a thick suspension with water. Here the addition of the alkaline reagents is effective in reducing the water content required to keep the suspension fluid. In fact, the amount of water present is not greater than that found in the same mixture in the plastic state, without the use of the electrolytes. The slip is poured into a plaster mold which absorbs water greedily, and hence causes the formation of a solid wall, conforming to the contours of the inside of the mold. According to the thickness of wall desired, the slip is left in the mold a shorter or a longer time, when the liquid still remaining is poured off. In this manner intricate shapes of clay ware can be readily produced. The process is used largely in the manufacture of sanitary ware, but has been extended to the making of such large and heavy articles as glass pots. The effect of varying amounts of the alkaline reagents upon different clays, the question of adsorption, the time factor, and a number of similar problems, offer a fruitful field of research in applied colloidal chemistry and which have received some attention in American technical literature.[6]

The effect of electrolytes upon clays in the plastic state as regards plasticity, drying shrinkage, strength, etc., is of an interesting character and has led to some useful discoveries, such as the prevention of drying cracks by the use of small amounts of sodium chloride or larger percentages of hydrated lime.

With reference to the effect of electrolytes in general, it might be stated that the presence of H ions is conducive to increased plasticity, while OH ions tend to reduce this quality. However, such phenomena as hydrolysis and adsorption may complicate the effects decidedly, and in the case of small additions we are undoubtedly dealing with very unstable equilibria. The effect of preheating clays, before fabrication, to temperatures as high as

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[6] Kirk, Trans. American Ceramic Society, 15, p. 573. Bureau of Standards' Technologic Paper No. 51, Bureau of Mines, Technologic Paper No. 126.

500° C., upon the colloidal structure, has brought out information which may be useful in dealing with clays possessing an excessive tendency to shrink and crack in drying.

The examples stated tend to show that we are gradually mastering the phenomena, both chemical and physical, occurring in the heterogeneous rock mixture known as clay. Well-known general facts, such as the laws governing evaporation, have been found very useful in the control of the drying process and in rendering harmless salts tending to deposit on the surface of clay ware, as the sulphates of lime and magnesia, by the introduction of equivalent amounts of barium carbonate or hydroxide.

With reference to the burning of clays, the amount of theoretical and practical information is increasing steadily. We are informed as to the dehydration temperature range during which the kaolinite molecule, $Al_2O_3.2SiO_2.2H_2O$, loses its combined water. The decomposition proceeds most rapidly at 500° C. but the last of the chemically combined water is not expelled before 800° C. The increase in the specific volume of clay upon dehydration and its increased solubility in acids in this state have been well established. At 850° C. the exothermic reaction of clays first detected by Le Chatelier [7] has been confirmed repeatedly though opinions differ as to the reaction involved.

Reactions associated with the impurities combined in clay, especially carbon and the hydrocarbons, pyrites, and calcium carbonate, are sometimes of far-reaching consequence. That the complete oxidation of carbon at a low temperature, while the clay structure is still porous, is of the greatest importance for the successful firing of clay products has been clearly demonstrated by Edward Orton, Jr., in his classic researches.[8] It is not an exaggeration to state that the amount of money saved the manufacturers of clay products by means of this specific information amounts to a considerable number of millions of dollars.

Considerable work has been done also in the study of the stages of incipient and complete vitrification of clays in firing. It is now generally understood that the contraction and consequent decrease in porosity is due to the action of surface tension, tending to contract the mass, and is made possible by the softening due to the effect of the fluxes. Interesting questions have arisen with reference to the speed of vitrification at different temperatures, the time effect at constant temperatures, etc., which have an important bearing on the control of the firing process. At the same time the question of composite eutectics of such complex systems demands consideration as well as that relating to the viscosity at different temperatures. These problems are very much complicated by the fact that we are dealing here with physically heterogeneous systems which are far from equilibrium. Even overburned clays, approaching fusion, are still undergoing changes due to solution and interaction as is shown by the curve of Fig. 2, in which the specific gravities of typical clays are plotted for increasing temperatures. It will be noted that the specific volumes are still undergoing a decided increase and that they will reach constancy only upon complete fusion.

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[7] *Comptes Rendu,* 104, pp. 1443, 1517.

[8] The Rôle Played by Iron in the Burning of Clays. Trans. American Ceramic Society, vol. v, p. 377.

FIG. 2.

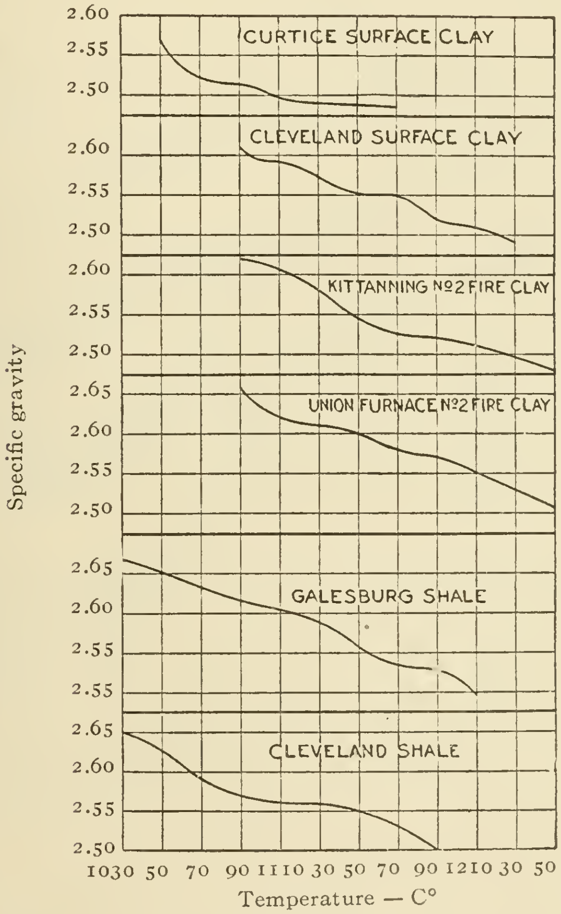
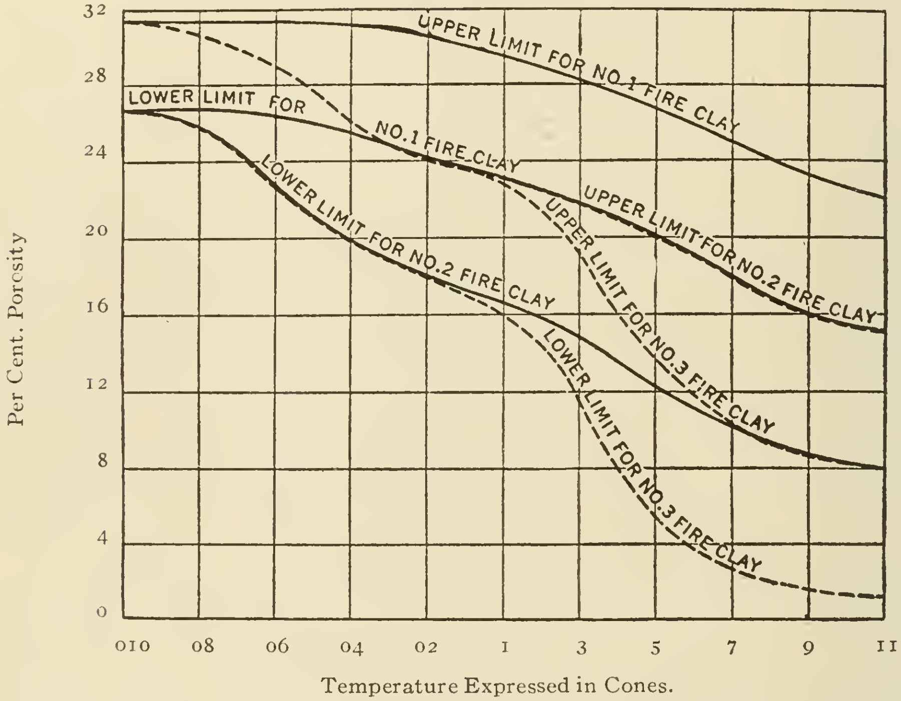


Diagram showing the continued decrease in the specific gravity of clays fired to temperatures above their vitrification point.

In the study of clays for the purpose of estimating their technical suitability, the most important relation is that between porosity and firing temperature under established firing conditions, such that the temperature increase does not exceed 25° C. per hour. A diagram illustrating this relation is shown in Fig. 3, and this method of judging the quality of clays is of great value. It was first proposed by Purdy[9] and makes possible a sharp differentiation between easily and difficultly vitrifying clays, and between low- and high-grade materials.

Fig. 3.



Purdy's porosity—temperature diagram used in classification of fire clays.

The explanation of the fusion phenomena entering into the discussion of vitrification has received powerful support from the theoretical investigations of the Geophysical Laboratory at Washington, but the field to a very large extent is far from being covered in its entirety. Through the study of the fusion and deformation of the more complex systems of silicates it will finally be possible to map out with a good deal of accuracy their behavior under industrial conditions.

The viscosity of the silicates at the higher temperatures, but below their fusing points, is technically of extreme importance.

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[9] Illinois Geolog. Survey, Bull. No. 9, p. 256.

If it were not for this property, it would be impossible to manufacture porcelain or other vitrified products. The evaluation of viscosity related to temperature is very essential in ceramic as well as metallurgical problems, where the deformation of refractories at high temperatures is sometimes of considerable practical significance. Mellor,[10] in the course of recent studies as well as others before him, has found it desirable to make a particular study of the decrease of viscosity of clays with temperature. The last-named investigator, in fact, has derived a mathematical relation between the temperature and the load in pounds per square inch, required to deform the materials which may be expressed by the equation:

$T = Ce^{-kw}$, where

T = deformation temperature in °C.,

C = deformation temperature in °C., without load,

k = constant,

w = load in pounds per square inch, and e = exponential constant. A number of other physical constants, such as the coefficient of expansion, the thermal conductivity, etc., have been determined for the several classes of materials with more or less accuracy.

One of the most potent tools in the study of vitrified or fused silicates has been found in the application of petrographic-microscopic methods. For instance, it is now possible by means of microscopic data to determine the composition of a porcelain as well as the heat treatment it has received. Similarly, we are in position to state whether silica refractories, so largely used now in the metallurgical industries and in by-product coke ovens, have been carried to the proper temperature, a point of great significance which may have an important bearing upon the permanency of costly furnace structures. Thus, we have in the illustration of Fig. 4 a microphotograph of a section of Japanese porcelain, showing the formation of crystalline sillimanite produced by the decomposition of the clay substance, and the solution of the quartz grains in the fused feldspathic magma. The work of Klein[11] relating to the microstructure of porcelain has proven of great value in bringing out the real facts concerning the vitrification process of feldspar—clay substance—quartz mixtures.

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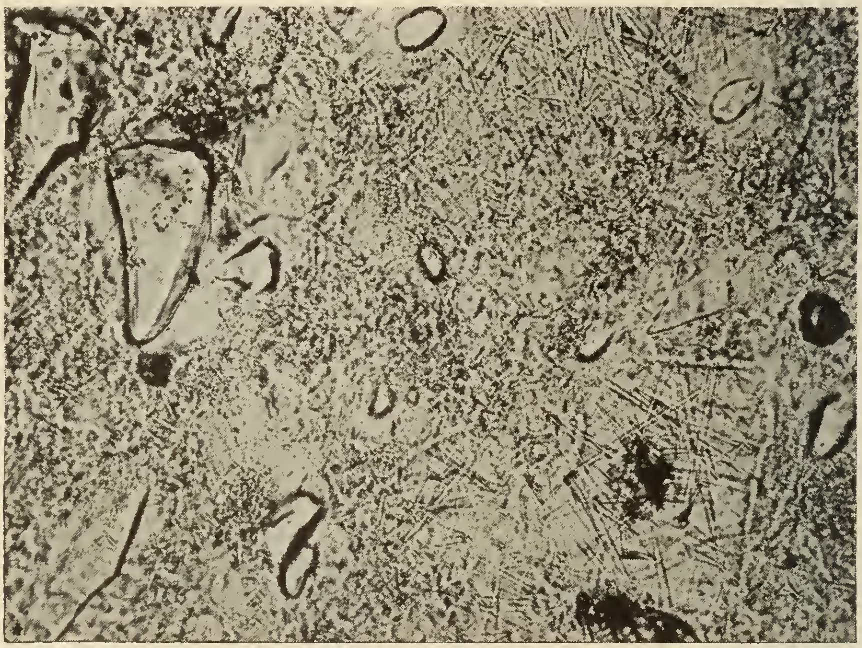
[10] Trans. English Ceramic Society, vol. xv, Part I, p. 117.

[11] Bureau of Standards, Tech. Paper No. 80.

Again, Fig. 5 illustrates the proper structure of a silica brick with but a small amount of unchanged quartz, most of this mineral having been transformed to cristobalite and tridymite. The deeply-fissured fragments, originally quartz, are characteristic of a well-burned product. Microscopic research, with all of its accessory technics, is to-day an indispensable adjunct of a ceramic laboratory.

During the firing process the character of the combustion gases, whether oxidizing or reducing, is of importance with reference to the ultimate color of the ware, and hence requires careful consideration. This applies especially to products coated with colored glazes, since it is not immaterial whether we produce, for instance, the green color of cupric or the red of cuprous oxide. Similar conditions prevail as regards the ever-present ferric oxide, with reference to the formation of ferrous or of magnetic oxide. In our modern clay working plants much skill is now being shown in the production of various colored face bricks by the use of oxidizing or reducing kiln atmospheres.

Fig. 4.

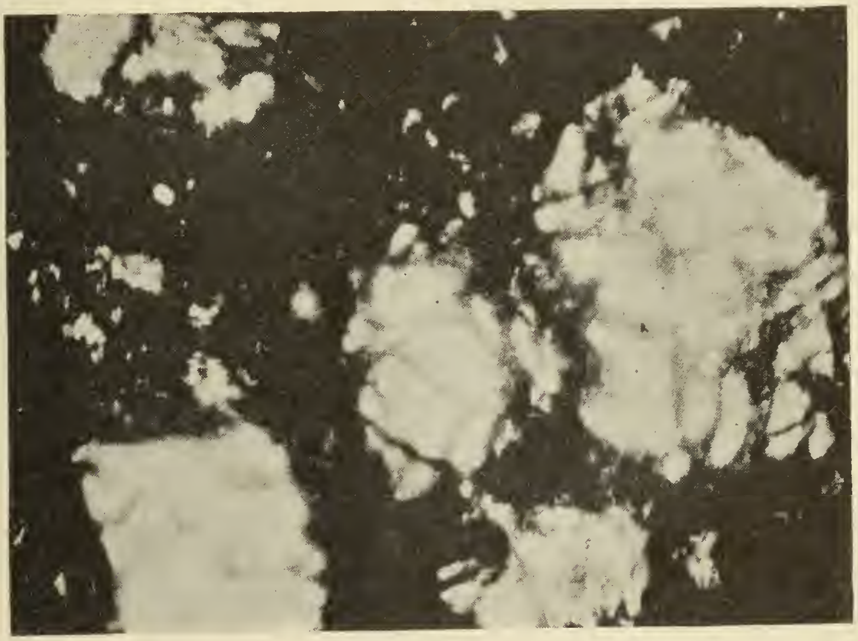


Micro-section (by Klein) showing structure of Japanese porcelain.

Theoretical speculations as to whether the silicates here under discussion are or are not ionized, when being vitrified, have not been without experimental evidence. Indeed, it appears to be true that these mineral mixtures show ionic conduction and such associated phenomena as polarization.

Interesting data have also been obtained in connection with the determination of the di-electric strength of vitrified bodies, and it has been found that there is a decided drop in the resistance of porcelain at temperatures as low as 200° C.[12] The testing of high tension insulators has become a well-established practice in electrical porcelain works.

FIG. 5.



Micro-section (by Klein) of well burned silica-brick.

The application of pyrometry in the ceramic industries has been quite extensive. The platinum platinum-rhodium thermocouple and with it the high resistance millivoltmeter are used in hundreds of works for controlling kiln temperature. Base metal couples are likewise employed in large numbers for lower temperatures. The pyrometric cones devised by Seger and manufactured in this country by Orton afford inexpensive means of fixing the finishing point of kilns, even though they do not measure temperatures. Since they are composed of silicate mixtures, their softening point expresses the effect of both time and temperature.

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[12] Trans. American Ceramic Society, 13, p. 469.

The physical properties of structural clay products, refractories, etc., have not yet been studied as thoroughly as the importance of the subject deserves. Certain classes of materials have received practically no attention. It would be well worth while if more consideration were given to this subject in the curriculum of the architectural and engineering departments of our colleges. In this connection both the intrinsic strength of the materials for different degrees of porosity and the strength of the fabricated products must be treated. In the case of building bricks a good deal of testing has been done both upon individual and built-up specimens, especially at the Watertown Arsenal under the direction of Mr. J. E. Howard, but the data has not been correlated for the different types of material. An attempt to do this has been made by the writer,[12a] but the available material is entirely too meagre in volume. Not only the mechanical qualities expressed by the compressive and transverse strength, the modulus of elasticity, resistance to shear, resistance to sudden temperature changes, and the thermal properties, but also the durability and resistance to weathering are of vital importance. In fact, the latter quality should receive most careful attention, considering the fact that hundreds of millions of dollars are being expended in the use of these products. Obviously, this applies to stone and concrete as well.

Of late efforts have been made to replace the time consuming and laborious freezing test, largely used in this connection, by accelerated tests, of which the most promising is the Brard process consisting in immersing the specimens in a boiling concentrated solution of sodium sulphate (Glauber's Salt) and drying them in order that the salt may crystallize. This test is sharp and decisive, but severe. There should be no difficulty, however, in modifying it, as has been suggested in recent work.[13]

This brief résumé of the investigative activities in connection with the ceramic industries indicates that we need not apologize for the part taken by American ceramists in the work covered by this field. To no small extent do we owe this condition to the technical work offered in ceramics by several universities and colleges, and to the agency of the American Ceramic Society.

[12a] International Engineering Congress, San Francisco, 1915.

[13] Howat, Trans. American Cer. Soc., 17, p. 249.

THE RAW MATERIALS OF THE UNITED STATES.

From the industrial standpoint, clays may be roughly divided into seven classes:

1. Primary kaolins, usually white burning, very refractory, and of low plasticity and strength.

2. Plastic kaolins, not as white burning as primary clays. May be very plastic.

3. Clays of the fire-clay type, ranging from materials of high refractories to those inferior in this respect. Certain highly refractory clays, called flint clays, are almost lacking in plasticity. Very plastic clays, called ball or bond clays.

4. Shales. Fine-grained, hard clays, showing well-defined cleavage and often slate-like in appearance. They differ widely as to composition. Many ferruginous shales are sources of the best paving brick. Shales, as a rule, are uniform over comparatively large areas, and hence have great industrial importance.

5. Alluvial clays. Of recent geological origin and found principally in old and new river valleys. Vary widely in composition and physical behavior, from clays of excellent plasticity to very sandy materials. As a rule, unsuitable for paving brick. Usually burn to a red color.

6. Glacial clays. Heterogeneous mixtures of clay with various rock débris. Frequently calcareous, causing clay to burn to a cream or buff color. As a class, difficult to work and hence suitable only for rude products.

7. Loess clays. Wind-blown deposits, usually silicious and hence of low plasticity. Used only for common bricks.

The United States is not deficient in any of the types of clay, although the distribution, of course, is not uniform, so that many states are lacking entirely in certain kinds of raw material. This question will be taken up in connection with the discussion of the several industries.

THE BRICK INDUSTRIES.

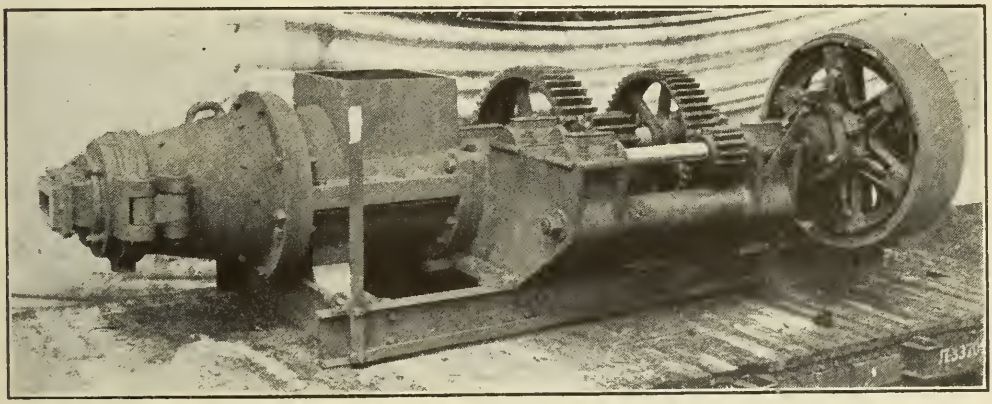
The manufacture of common building bricks is extended practically over the entire country, though the materials available vary widely. Thus New York draws upon the alluvial clays of the Hudson Valley, Philadelphia upon the surface clays and to a limited extent upon shales, Chicago upon calcareous, glacial clays, New Orleans upon extremely sandy alluvial clays and a large part of the South upon characteristic red surface clays, sticky in character, while Pennsylvania, Ohio, Indiana, southern Illinois, Iowa, Missouri, Kansas, Oklahoma, Kentucky, Arkansas, Alabama, Washington and Oregon have available great deposits of shale and in connection with the carboniferous series of rocks also plastic fire-clays of the number two grade. Certain states like Florida and Michigan are rather poor in clays possessing good working qualities. The glacial clays of Wisconsin, Minnesota and North Dakota frequently offer considerable difficulty in brick manufacture. From this it is evident that the quality of the bricks must vary considerably in different localities. The hard-burned, vitrified building brick of Ohio and Pennsylvania is an entirely different product from that obtainable in Louisiana or in the Chicago district. It is evident, therefore, that it is a difficult matter to establish specifications for building brick which are fair to all the materials, when we are dealing with variations in compressive strength from 20,000 to 1000 pounds per square inch and in water absorption from 1 or 2 to 30 per cent.

The old art of brick-making has undergone considerable changes within the last 20 years. The hand-molding process has been largely replaced by machine methods, employing either the soft clay, stiff clay or dry-press method. The American brick-making machines, both as to capacity and construction, are probably the superior of any in the world. The stiff clay machines predominate at the present time, although it is necessary to resort to the use of the soft-clay machine or dry-presses in dealing with clays deficient in plasticity. Fig. 6 illustrates a high-grade, stiff-clay machine, which forces the clay through a die in the form of a column which is cut into bricks by means of an ingenious automatic apparatus, employing moving wires for this purpose. In Fig. 7 a modern heavy dry-pressing machine is shown. The capacities of the stiff-clay machines are very large; the production of 100,000 bricks per unit and per day of 10 hours is not uncommon.

No longer is the sun's heat called upon to dry the molded bricks, but dryers artificially heated are employed for this purpose. In these the bricks are placed on cars and the latter run through heated tunnels. Two systems of dryers are in use, the continuous and the periodic. In the former the cars are constantly being discharged and replaced, the temperature and humidity conditions being about the same all of the time.

Roughly three zones may be distinguished in the operation of these dryers—the steaming, the evaporating and the heating zone. In the first the wet bricks must be warmed up without undergoing any appreciable evaporation; in the second, increasing evaporation is permitted as the cars travel along, due to the higher temperature and lower humidity, and in the third, the last portion of the water is expelled and the dry bricks heated somewhat below the temperature of the incoming hot air. The air and vapor pass through the tunnels in the direction opposite to that of the cars. The heat required for the evaporation of the water is obtained either from cooling kilns, steam pipes, metal-covered flues, heated from separate furnaces, or even from the combustion gases. The heat from cooling kilns is used most largely and has proven an economic necessity where periodic kilns are employed. Large fans are necessary, both for removing the heated air from the kilns and the moist air from the dryer. This type of dryer is the most economical when operated properly, but is not well adapted for operating with sensitive clays, having a tendency to check and crack in drying. Also the dryer is afflicted with certain inherent defects as unequal heat distribution due to the horizontal direction of the air current. For this reason recent developments have brought about certain changes, especially in carrying the steaming temperature to a very much higher point and in the use of smaller fans for cross circulation.

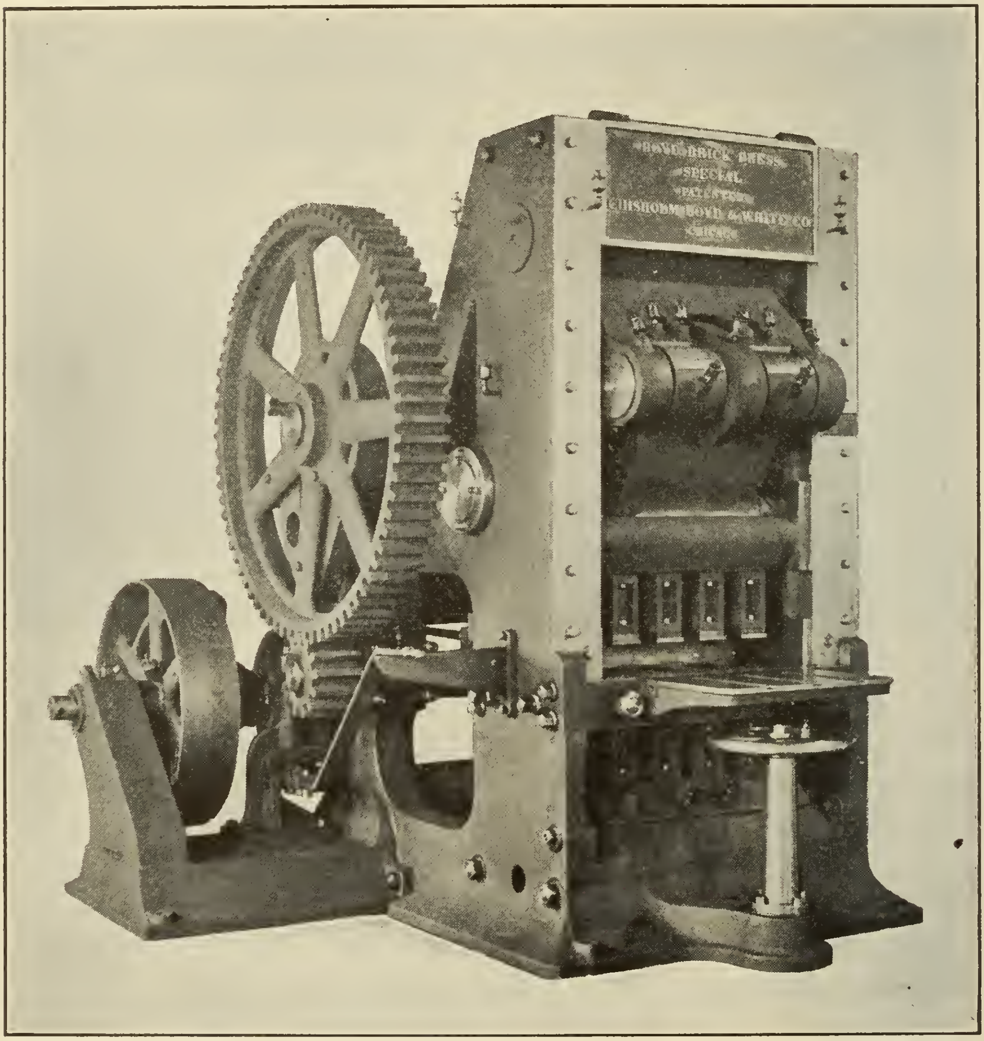
FIG. 6.



Auger brick machine.

The second type of tunnel dryer is periodic in operation, a tunnel being filled with the loaded cars, after which it is closed and heating begun. The atmosphere soon becomes saturated with steam and at the same time the temperature rises, thus preparing the ware for the evaporation process which is to follow. Then the small stacks, of which there are a number on top of the tunnel, are gradually opened and the drying allowed to begin. This periodic system permits of complete control of the drying and hence even the most sensitive clays can be carried through this operation without harm.

FIG. 7.



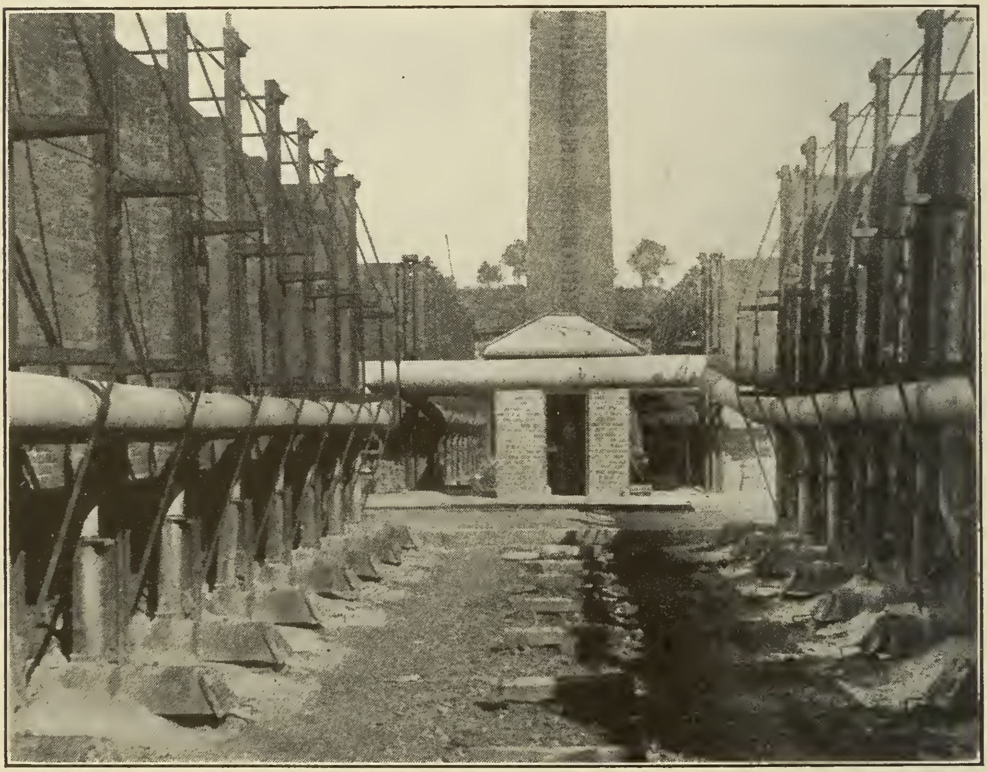
View of dry press brick machine.

The burning of the bricks is of course the most important part of the process. There are used for this purpose the old-fashioned clamp kiln, the down-draft and the continuous kiln. A new continuous type of kiln, the tunnel kiln, is also appearing on the market. For mass production the clamp kiln is holding its own, especially because it is adapted admirably for mechanical setting where units of 500, or even 1000, bricks are taken from the dryer cars and set in position in the kiln. Similarly, the burned bricks are removed from the kiln in the same fashion. This modern phase of brick handling is known as the Penfield system. The clamp kiln, so familiar to us, suffers under the great disadvantage of producing a considerable percentage of soft-burned bricks, a difficulty almost impossible to overcome. It is this defect and not lack of fuel economy which is leading to the gradual displacement of this type. This is especially true in localities where there is a well-established demand for a hard, vitrified product. Still, the clamp kiln will hold its own for a long time to come owing to its simplicity and cheapness of construction and the ease of setting and removing the ware which are economic advantages of importance.

The down-draft kilns, both square and round, are used wherever a uniformly hard product is required, and they are indispensable in the manufacture of paving brick. Lately also, the use of producer gas has been introduced in connection with down-draft kilns illustrated in Fig. 8. Considered from the standpoint of heat efficiency, all periodic kilns, whether of the old-fashioned clamp or the down-draft type, are exceedingly wasteful. It has been determined that even in the best operated periodic kilns not more than 25 per cent. of the fuel is actually utilized for the burning of bricks. This condition is still more strikingly illustrated in the case of pottery kilns where the heat actually used is not more than 5 per cent. of that introduced. The question of fuel economy is, therefore, becoming a question not only of importance with reference to these particular industries but also to the country at large, since any kind of fuel waste is against public policy. It must be confessed that in the question of fuel economy we have been negligent and that in this respect our methods of burning clay products are inferior to those of Europe. However, there is a decided current at the present time towards the replacement of the periodic by continuous kilns.

The latter, first invented by Hoffmann and Licht, embody the principle of utilizing both the heat of the cooling ware and the heat contained in the products of combustion, thus making possible almost complete regeneration. These kilns are in the form of an endless tunnel, oblong in form, so that there are two long tunnels, side by side, connected at the ends. Two forms of kilns are to be distinguished, the one being essentially a continuous, uninterrupted tunnel, the other a series of chambers, built side by side and connecting with each other. The first type is intended primarily to be fired from the openings in the top, using slack as fuel; the second one, is especially adapted to the use of producer gas and was first introduced by G. Mendheim and his associates. The top firing with small coal has not found great favor among American manufacturers. For this reason, the continuous principle was partially sacrificed by firing both through the charging doors of the kiln and in the usual way through the openings in the arch. This system is represented by a number of installations and is known as the Haigh Kiln.

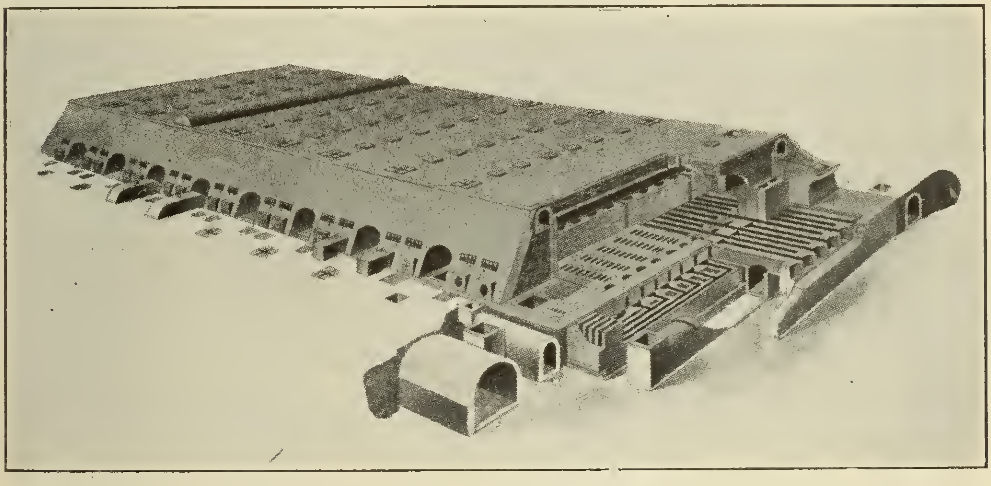
FIG. 8.



Down-draft kilns fired with producer gas.

Since the chamber type of the continuous kiln is well suited for producer-gas firing, it is finding application especially in the burning of facing and paving bricks. The first successful kiln of this kind was that of Youngren, fired on one side of the chamber, which was later improved by Rodgers and others and has been found very successful. The gas is usually introduced through flues in the bottom of the kiln. More recently the double-fired chamber of the Richardson kiln, having gas ports on both sides, has been introduced and is of considerable promise. The construction of the last-named kiln is illustrated in the view of Fig. 9.

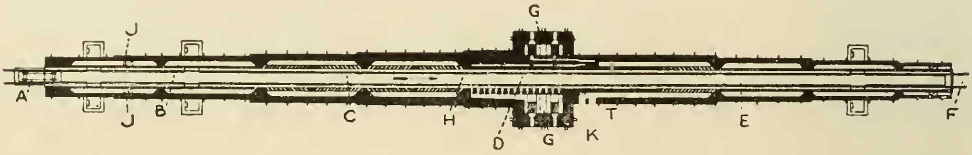
FIG. 9.



The Richardson gas-fired continuous kiln.

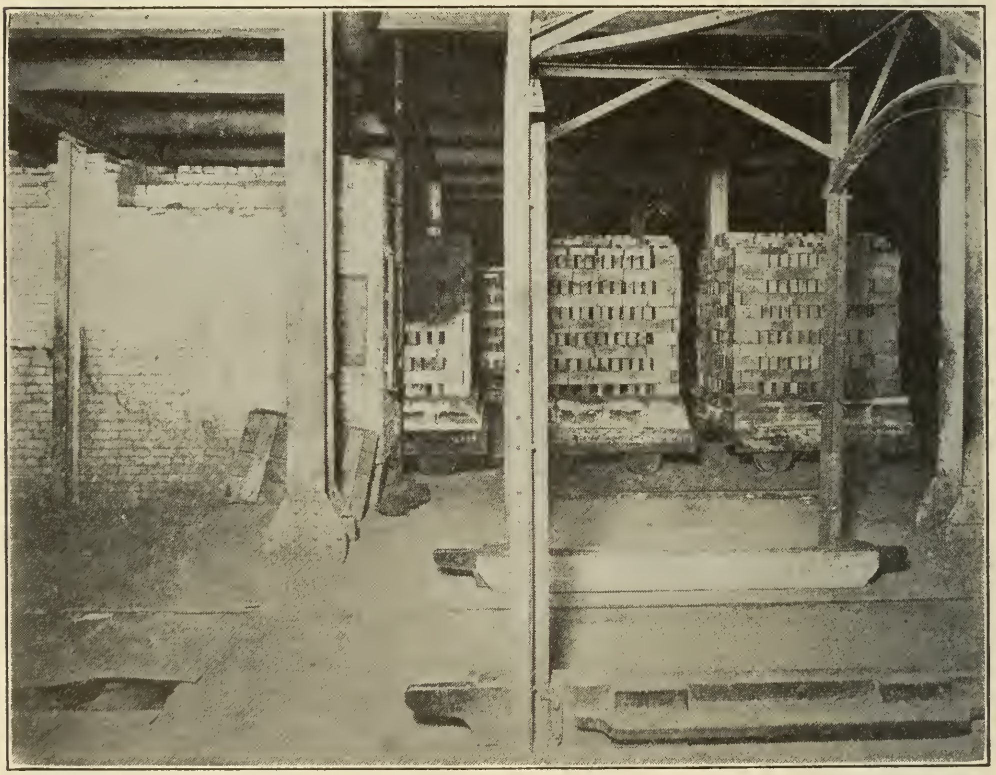
The tunnel type of kiln has of late received considerable attention and is represented by two systems. In the first, the bricks are loaded on cars which are gradually pulled through a tunnel, having furnaces or gas ports on both sides along the middle section. The cars obviously must be provided with platforms, built up of refractory material in order to protect the running gear which is cooled by a current of air. The tunnel is thus divided into the firing chamber and a channel containing the track and iron work of the cars. Leakage of gases is prevented by longitudinal sand seals on both sides of the car. The direction of the gases is opposite to that of the cars. Thus the heat of the combustion gases is used to preheat the ware and the fired product gives off its heat to the air used in combustion The second feature is worked out more satisfactorily when producer gas is used as fuel. This system of the tunnel kiln is quite old in its inception and the first European patent was probably issued as early as 1840. The best known constructions are the Faugeron kiln in Europe and the Didier-March kiln in the United States. The plan of the latter kiln is given in the diagram of

Fig. 10.



Plan of tunnel kiln used for burning brick.

Fig. 11.

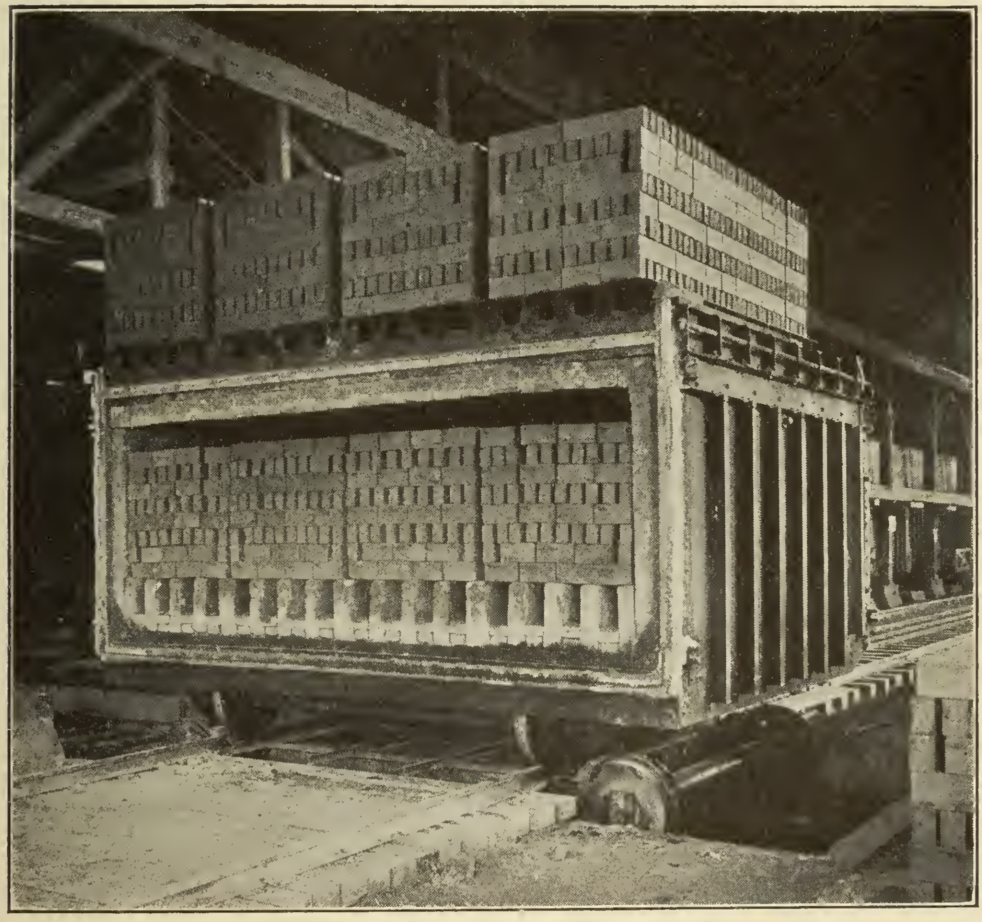


View showing cars loaded with brick about to enter tunnel kiln.

Fig. 10. It will be noted that by the use of flues separated from the tunnel by means of perforated walls, a kind of serpentine motion is imparted to the flames which is caused to pass from the tunnel to the flue, where it again changes its direction back to the tunnel. The photograph of Fig. 11 shows cars loaded with bricks about to enter the kiln.

The second system of the tunnel kiln type for burning bricks is of American origin and was invented by Alexander Scott. It is based on a most ingenious idea, namely that of dividing the tunnel kiln in sections and putting them on wheels so that the kiln is made up of a series of movable chambers. The kiln sections thus form a train composed, say, of 13 or 14 such cars. As soon as a chamber has been fired and cooled it is removed and a section containing a fresh charge attached to the other end of the train. The construction of the cars is illustrated by the photograph of Fig. 12. The firing is done by means of producer gas, movable connections being used which attach to four cars in the middle of the series.

FIG. 12.



View showing unit of Scott tunnel kiln.

All tunnel kilns have in common, not only the fuel economy inherent in the principle, but they also render the placing of the ware and its removal much easier and cheaper.

The common brick industry has suffered somewhat from competition with concrete. The manufacture of face brick, on the other hand, has established itself more and more firmly by offering to the building public, not only a large variety of colors and shades, but also by producing pleasing rough textures, known as texture or tapestry brick and other trade names.

Both for the purpose of reducing the cost of the laying up of walls and of providing air spaces which are desirable for apparent reasons, there has been a remarkable growth in the manufacture of hollow tiles, using both vertical and horizontal webs. In addition special shapes, such as the Dennison interlocking tile, Fig. 13, have been designed and have proven very successful. Retaining the idea of the brick unit another kind of tile has been developed, the Fiske type, which makes possible the use of the artistic effects of brick.

An important development of the brick industry is the manufacture of paving blocks which has kept pace with the expansion of the network of paved streets and roads. Realizing that the success of brick-paved streets is as much or more dependent upon a proper method of construction than upon quality of the material, this branch of the industries has made consistent and effective efforts towards careful and thorough construction. Of late, monolithic brick pavements in which the blocks are laid in wet concrete have gained in favor. The largest producers of paving blocks are the states of Ohio, Pennsylvania, West Virginia, Indiana, Illinois, Kentucky, Kansas, Washington, Oklahoma, Alabama, Tennessee and Oregon. The geographical area of shales suitable for this purpose is practically limited to the states mentioned, owing to the rigid requirements governing paving blocks.[14] The adoption of a standard rattler test has made it practically impossible to market anything but products of the highest grade.

In the field of fire-proofing, in the protection of steel columns and girders of sky-scrapers, clay products must now compete with concrete, gypsum and other materials. As a result the volume of this business has somewhat decreased. This loss has been compensated for by the increased production of hollow tiles, conduits and similar products.

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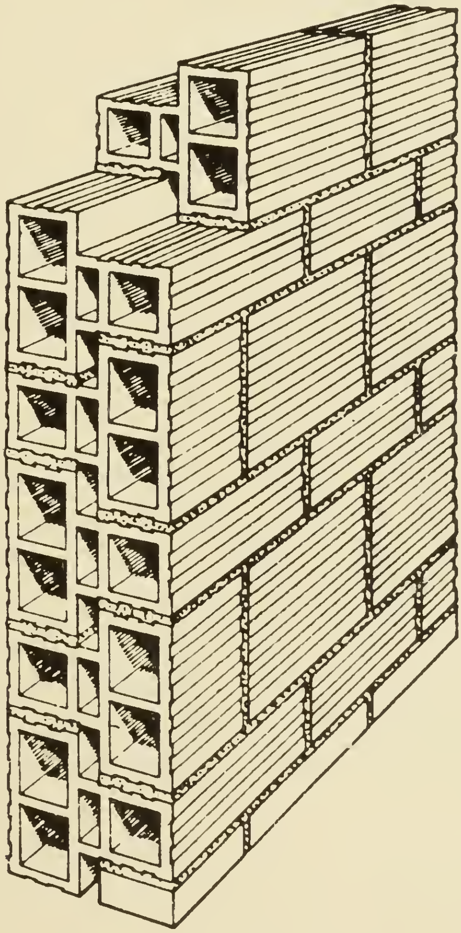
[14] Yearbook Am. Soc. for Testing Materials, p. 396.

The sewer pipe industry also has felt the competition of concrete, especially in the larger sizes, but it has managed to hold its own. The adoption of segmental sewers has been found an effective means of meeting the new competition.

FIG. 13.



Wall section of interlocking tiles.

THE REFRACTORIES INDUSTRIES.

Refractory materials are indispensable in the practice of the metallurgical arts, in the melting of glass, the clinkering of cement, in the ceramic firing processes and last but not least, in the generation of steam. The principal types are the clay, silica, magnesite and aluminous refractories.

Clay Refractories.—For the sake of convenience three kinds of clay materials may be recognized in this connection, called for convenience, No. 1, No. 2, and No. 3 refractories. The greatest heat resistance is shown by those clays corresponding most closely to the theoretical kaolinite composition, 46.3 per cent. silica, 39.8 per cent. alumina and 13.9 per cent. chemical water, which upon heating becomes 53.8 per cent. silica, and 46.2 per cent. alumina, and by the so-called bauxitic clays. The latter are admixed with some bauxite which may raise the alumina content as high as 60 per cent. (in the hydrous state). The increased amount of alumina brings about a decided increase in the refractoriness of the material. Clay of the purest type possible, kaolinite, has a softening temperature corresponding to the melting point of platinum, 1755° C., or expressed in standard pyrometric cones, to cone No. 35. Owing to the greater or smaller amount of impurities, such as silica in the form of quartz, feldspar, lime and magnesia, this softening temperature is hardly ever realized. A softening temperature of 1725° C. is about as high as is reached by high-class fire-clays, such as the flint clays. Clays containing bauxite may soften at temperatures as high as 1800° C. A high grade of No. 1 fire-clay should not soften below cone 31 or approximately 1685° C. This point, therefore, would be about the dividing line between No. 1 and No. 2 fire-clays, though others place the limit considerably lower. The division line between the No. 2 and the No. 3 clay refractories would be at cone 28, or roughly 1635° C. Clays softening below this limit might be classed as No. 3 refractories. Although this arbitrary classification may be considered too exacting by some, it has worked out quite satisfactorily in a clay-testing practice extending over a number of years.

Fire-clays may also be divided into two types of clays according to whether they are plastic and dense burning at comparatively low temperatures, say, around 1200° C., or whether they are open burning, *i.e.*, retain their porosity within this temperature region. The clays of the second class are also, as a rule, less plastic than those of the first. The characteristic behavior of the denser burning clays is due, of course, to their higher content of fluxes.

Silicious fire-clays, that is clays with a silica content above 75 per cent., possess a lower softening temperature than the highest grade fire-clays and are influenced more potently by the presence of fluxes. It is more important that a silicious fire-clay be low in the basic constituents, iron oxide, lime, magnesia, potash and soda than an aluminous one since the lowering of the softening point is more marked. On the other hand, silicious clays have a decided advantage over the average clay fire-brick in that they are not subject to shrinkage in use and are able to carry considerable loads at furnace temperatures without showing any appreciable deformation. They are able to stand up well at temperatures not far removed from their ultimate softening point while clay fire-brick cannot safely be carried to temperatures within 150° C. below the deformation point. At the same time, clay fire-bricks show considerable contraction and soften sufficiently even at temperatures as low as 1400–1450° C. to render them unable to carry loads greater than 10 pounds per square inch. This statement needs to be modified, however, in that high clay fire-bricks may be manufactured by the use of highly calcined No. 1 clay (grog) and by high burning of the material so that the contraction is very small and the load-carrying power quite high. In doing this the contraction of part of the clay is practically completed in the calcination and in the burning of the bricks, so that but a small shrinkage can take place later. At the same time the compact structure is able to resist the usual pressure conditions in furnaces satisfactorily. Such a process of manufacture is expensive. All non-silicious clays tend to shrink in burning, due in part to the colloidal contraction and in part to the effect of the fluxes which are active in lowering the viscosity of the clay, thus bringing about a gradual liquefaction. In silicious clays this shrinkage is practically eliminated, not only on account of the much smaller amount of clay substance present, but also on account of the volume increase of the quartz in its transformation to cristobalite and tridymite. This volume change may be great enough to cause expansion of the brick upon burning rather than contraction. The high silica content, however, brings with it certain disadvantages such as inability to withstand sudden temperature changes, which does not apply to clay bricks.

Silica Refractories.—These are principally produced from a mixture of ground quartzite and lime paste, so that in the fired product the silica content may be from 94 to 97 per cent., and that of the lime about 2 per cent. The firing of the dried bricks is carried to quite a high temperature, usually to above 1500° C. In the burning the lime bond tends to form a mono-calcium silicate and the quartz is transformed to cristobalite, an intermediate crystalline modification of silica. This transformation is coincident with the expansion of the brick, usually three-eighths inch to seven-sixteenths inch per linear foot over the mold measurements.

This linear expansion may be used as the criterion of the proper degree of burning, though it is by no means completed in the kiln but continues upon heating the bricks in use. The cristobalite, constituting about 80 per cent. of the finished silica brick, is not the stable phase at the temperatures involved but is further transformed to tridymite. Smaller quantities of this crystalline modification of silica are usually found in silica brick and some time after the latter are in use, provided the temperature is sufficiently high, it becomes the predominating constituent. Thus in open-hearth or glass furnaces the silica brick structure consists mainly of tridymite.

Although the refractoriness of silica refractories is lower than that of the high-grade clay bricks, corresponding to about 1700° C., their effective, useful temperature range is very extensive. Their rigidity and freedom form deformation at high temperatures, say 1600° C., is superior to that of clay refractories. Failure as a rule occurs quickly near the softening temperature and there is no long interval during which serious deformation may occur.

The one difficulty associated with the use of silica brick is their inability to stand up well under conditions of sudden heating and cooling. When subjected to such treatment they tend to spall and break down, especially if cooled below 600° C. Silica bricks are made also in which clay is introduced as a bond in place of the lime. This class of ware resembles the silicious fire-clays in behavior. As a rule they are not quite as satisfactory as the lime-bounded materials, though they are somewhat more resistant to sudden temperature changes.

Aluminous Refractories.—The use of bauxite and mixtures of bauxite and fire-clay is assuming larger proportions than it has in the past. This is particularly true at the present time when, due to the scarcity of magnesite, a substitute for the latter is being sought. From accounts which have been obtained it seems that it is possible to use refractories of this type successfully for purposes where magnesia seemed indispensable. The hydrous bauxite ores usually are impure, containing as a rule, 5 to 6 or more per cent. of ferric oxide. This applies to most American bauxites. The melting point of pure alumina is about 2049° C. but that of bauxite does not as a rule exceed 1820° C. A very high shrinkage upon heating is characteristic of bauxites and hence it is important that as large a part of the material as possible be previously calcined. Unless this is done and the calcination carried to a high temperature the shrinkage of the product in use will be so high as to render it very unsatisfactory. Bauxite tends to contract also under pressure at furnace temperatures and hence is not so well adapted for uses where severe load conditions prevail. Owing to the feebly plastic nature of bauxite, bricks consisting of calcined and raw bauxite are rarely made. Usually a good fire-clay is employed to bond together the calcined bauxite. This naturally reduces the refractoriness of the mixture so that bauxite-clay fire-bricks do not, as a rule, possess a softening temperature above 1800° C. Bricks of this type are sold on the basis of the alumina content.

Greater refractoriness can of course be reached by the use of refined bauxite from which a large part of the iron oxide has been eliminated by chemical treatment.

Alumina is also an important constituent of refractory porcelain such as is used for pyrometer tubes, the so-called Marquardt porcelain. Here a considerable amount of alumina, previously calcined together with some feldspar, is introduced as the non-plastic portion of the mixture which in addition contains more feldspar and plastic kaolin. The fact might be mentioned that Marquardt porcelain of good quality has been produced by the Pittsburgh laboratory of the Bureau of Standards, covered both with a bright and a matt glaze.

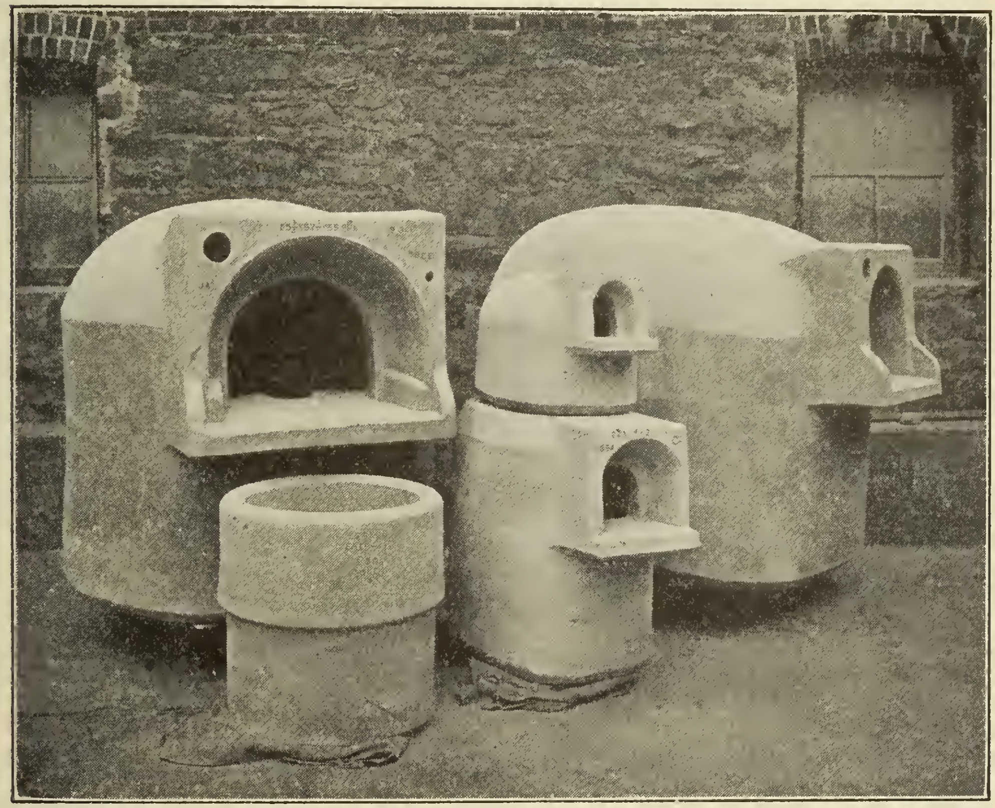
Magnesia Refractories.—The magnesite products represent typical basic refractories. Two kinds of magnesite are to be distinguished, rocks approaching pure magnesite in composition such as the Grecian and California materials and the impure ones, containing from 3 to 8 per cent. ferric oxide and more or less silica, of which the Austrian magnesite is characteristic. The melting point of pure magnesia is very high, about 2800° C., but that of magnesite brick rarely exceeds 2170° C. Owing to the extreme heat resistance of the material and its great shrinkage, about 50 per cent., by volume, pure magnesite is not suitable for refractory purposes since it would be exceedingly difficult to reduce it to practically constant volume, while owing to the fluxing action of the ferric oxide in the impure material the latter is more easily compacted.

The calcination of the magnesite is very important and in Europe it is conducted in shaft kilns working with forced draft. Rotary kilns would be well suited for this purpose. The dead burned magnesite, after having been crushed, is then intimately mixed with some low-burned magnesite, moistened with water and shaped into bricks under considerable pressure. The soft-burned magnesite functions as the cementing material. The bricks are then dried and burned in kilns to a high temperature. Magnesite bricks, owing to their basic nature and high heat resisting quality form a valuable refractory. The shortage of magnesite due to the European war conditions has made it necessary to look about for substitutes. In many cases bauxite materials have been found very satisfactory and it has been reported from several sources that this material has been permanently adopted. Dolomite has also been used as a substitute. For this purpose impure dolomite can only be used as it is necessary to "dead burn" the material as much as possible before attempting to make it either into bricks or to tamp furnace bottoms with it. A fairly high content of iron oxide is to be preferred, as in the case of magnesite and the calcination temperature should be carried as high as possible. Attempts have been made also to coat the crushed dolomite with a pulverized slag suspension in water so that upon burning a protective coating would be formed on the surface. The calcined dolomite, crushed to the desired fineness, is then mixed with hot tar as soon as possible and molded into bricks. These then must be burned again in order to remove the tar and bring about some consolidation of the particles. For tamping tar likewise is used as the bonding material. Dolomite material of this sort invariably slakes upon standing in the air. In spite of this difficulty it has been used to a considerable extent in European practice for many years.

In connection with the development of the by-product coke oven silica refractories are of the utmost value, since they furnish the bulk of the material used. Poor quality of the bricks and blocks or of the silica mortar used would be disastrous to the complicated and expensive structures used in this industry.

The European war has had some effect upon the refractories industries employing very plastic fire-clays for bonding together grains of calcined or other non-plastic material. This applies especially to the makers of glass pots and similar accessories used in the glass industry and to the manufacturers of graphite crucibles. The bond clays formerly employed to a large extent were the German clays from Gross Almerode and Klingenberg, respectively. The situation has been met very successfully by the glass pot-makers and somewhat less so by the crucible people by using American clays. The reluctance of some manufacturers to use mixtures of several domestic clays in place of one clay has caused some delay in making progress. Since in the United States we have a considerable variety of refractory bond clays [15] there is no inherent reason why the clays formerly imported should not be replaced by American materials. In Fig. 14 some examples of glass pots made entirely from American raw materials are presented.

FIG. 14.



Covered glass pots.

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[15] Bureau of Standards, Tech. Paper No. 79.

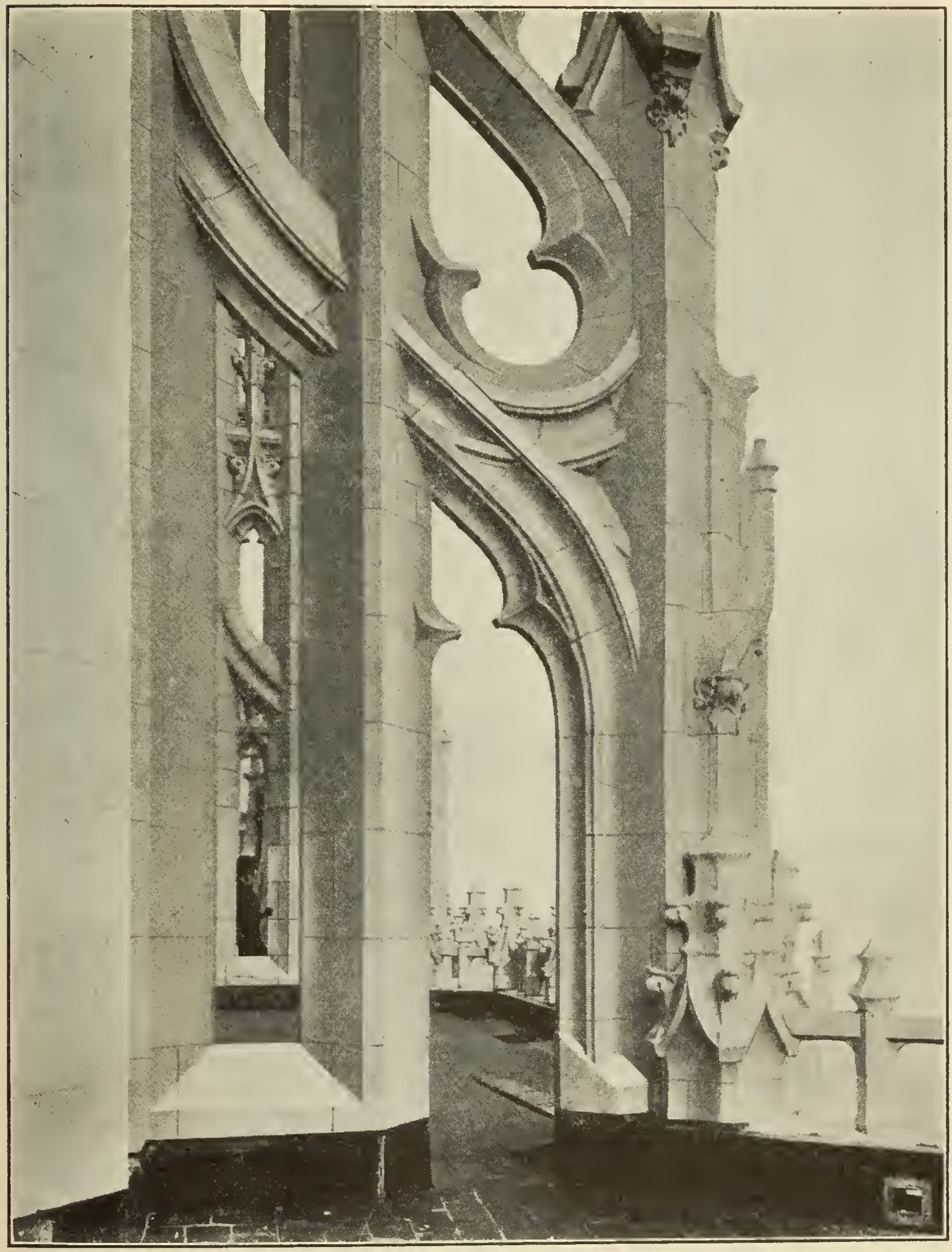
ARCHITECTURAL TERRA COTTA AND TILES.

It is not perhaps realized that our large cities are rapidly becoming examples of burned clay architecture. The excellent frost and weather resistance of terra cotta, its fireproof character and strength, the readiness with which it can be made to assume any shape, color and texture, together with its comparative cheapness have caused it to become a largely used building material. This development is strictly American since nowhere else has architectural terra cotta been developed to such a remarkable extent. In meeting the demands of the architect the American terra cotta industry has made great achievements both from the artistic and the technical standpoint. Fig. 15 shows a detail view of the terra cotta construction of the Woolworth building, New York, a city whose sky line may be said to represent almost entirely a characteristic combination of steel and terra cotta. Similar artistic and technical progress has also been made with reference to interior decoration by means of tiles both for walls and floors. From the utilitarian standpoint, that of attaining practical aseptic conditions, maximum amount of reflected light, etc., the use of plain, glazed tiles and glazed bricks in public buildings, is rapidly increasing.

THE POTTERY INDUSTRIES.

The pottery made in the United States at the present time may be said to consist of the following types: Stoneware, majolica, white ware, and porcelain. The old-fashioned stoneware pottery, such as crocks, jugs, etc., has shown a great drop as regards output and appears to be approaching extinction. It has in part been replaced by modern developments in the production of chemical stoneware, formerly a European specialty, which is now experiencing a rapid growth in the United States. This development has reached such a point that the future will probably see but little importation of ware of this kind. The skill shown by American makers in this branch of industry is illustrated by the photographs of illustrations 16 and 17. The rapidity with which the manufacture of chemical stoneware has met the recent extraordinary demands of the chemical industries is surprising considering the fact that a large proportion of this kind of ware was formerly imported from Europe. This fact calls attention to the close coördination between widely different industrial fields, in this case the clay and the chemical industries, which is necessary if we are to be in a state of true industrial preparedness.

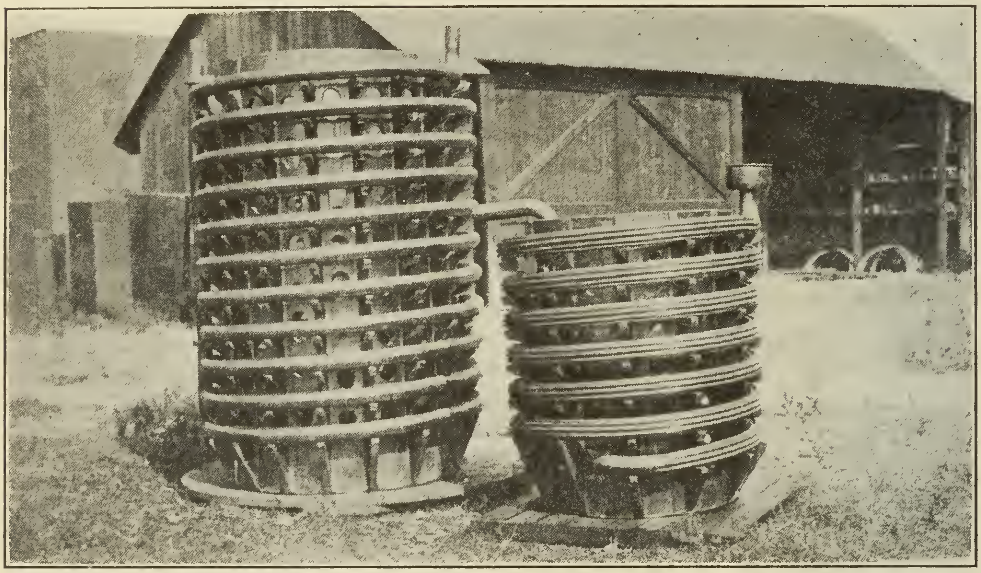
FIG. 15.



Detail of difficult terra-cotta construction.

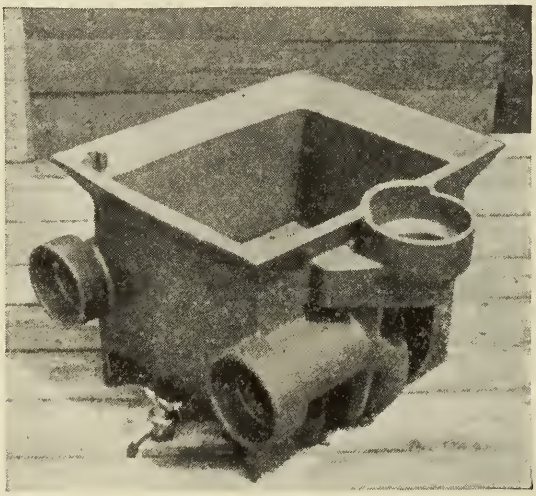
However, there are still other possibilities for the stoneware clays of Pennsylvania, Ohio, Indiana, Kentucky and Illinois which have not yet been realized up to the present time in the production of kitchen specialties, cooking ware, containers for the drug trade, etc. It would be necessary, however, to produce ware of more attractive appearance than was possessed by the old crude stoneware. The same type of clay is also particularly

FIG. 16.



View of stoneware condensing coils.

FIG. 17.



View of complicated stoneware apparatus.

suited for the manufacture of glazed bricks, floor tiles, etc. It would seem thus that the old stoneware industry is capable of being revived in several directions.

Majolica pottery is being made in considerable quantities and in low-priced grades in the form of jardinieres, etc. A gradual improvement is being observed as regards the appearance of this kind of pottery and some of it may be considered as belonging to the type of semi-art ware.

The table ware produced in the United States consists essentially of two kinds of pottery, white ware and porcelain. The former possesses invariably a white, porous and opaque body while the latter is white, impervious to liquids, dense and more or less translucent. According to the degree of porosity there are several grades of white ware, that called "white granite" being the densest and whitest. Trade names such as "semi-porcelain," "Ironstone China," "Vitrified Hotel Ware," etc., are apt to be misleading since no pottery body should be termed porcelain or vitrified unless it really does not absorb water and shows the characteristic dense structure of porcelain. White ware bodies may absorb from four to ten per cent. of water. Both white ware and porcelain are produced from a mixture of kaolin, ball clay, feldspar and ground quartz (flint), the difference in composition being principally a smaller content of feldspar in the case of the white ware, and a larger proportion of this constituent in porcelain. Since feldspar is the fluxing and glass-forming component it is evident then that more of it is required to produce a vitreous body than a porous one. The temperature of firing of porcelain likewise is higher.

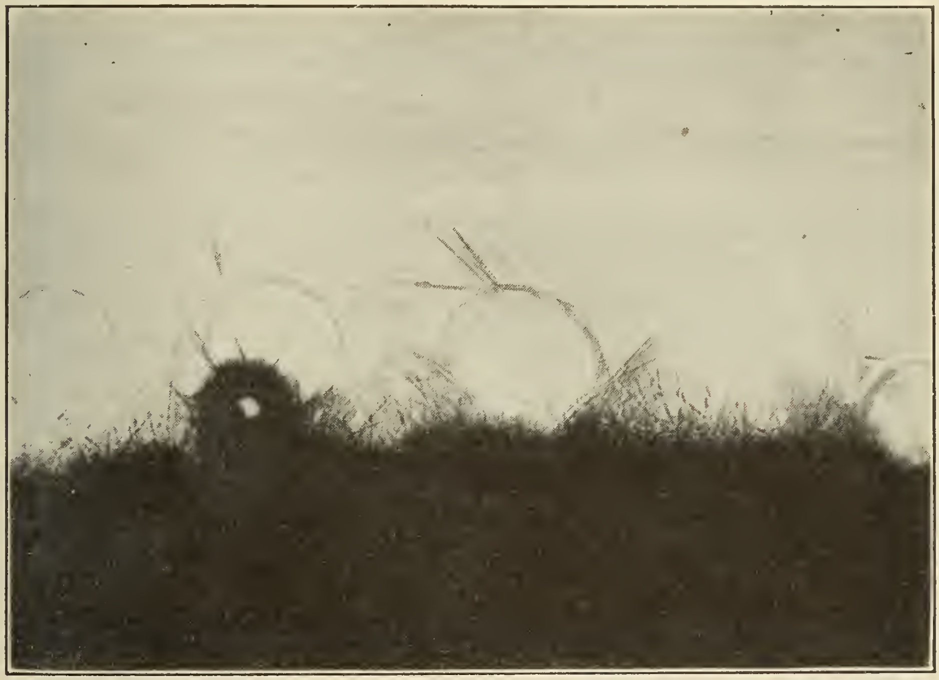
In the manufacture of white ware, of the composition: Kaolin 35 per cent., ball clay 15 per cent., feldspar 15 per cent. and flint 35 per cent., the first or biscuit firing carries the temperature to about 1290° C. while the glaze or glost burn does not as a rule exceed 1190° C. This practice follows that employed in the manufacture of the English earthenware with the difference that the latter has its glaze fused at a lower temperature than is common in American potteries, not exceeding as a rule 1120° C. The glaze of the English earthenware is hence considerably softer than that of the domestic ware, a fact not commonly realized by users.

American porcelain consists usually of about 46 per cent. of clay (kaolin and ball clay), 24 per cent. of feldspar and 30 per cent. of ground quartz. In its first firing it is carried to a higher temperature than white ware, usually to approximately 1330° C., in order that the fusing feldspar may cement together the quartz and clay to a vitreous, non-absorbent, and translucent mass. The glaze is fused on at practically the same temperature as in white ware. It is evident that the manufacture of American porcelain is derived from white ware practice which again has come to us from the English earthenware. On the other hand, the domestic porcelain differs quite radically both from the English bone china and the hard porcelain of the European continent. The glassy matrix of bone china is composed of a solution of feldspar and calcium phosphate (due to the use of calcined bone) and the material, although of beautiful texture is very much more fragile. Its glaze, like that of English earthenware is quite soft, due to the high content of lead oxide and boric acid. The European hard porcelain, on the other hand, reverses the English and American process inasmuch as the first burn (biscuit) is carried only to a very low temperature, about 990° C. The glaze is then applied and the ware finished at a temperature of approximately 1410° C. A glaze maturing at this temperature must in the nature of the case be free from lead oxide and boric acid and hence is certain to be very much harder than the white ware and the bone china glazes. The body and the glassy coating thus unite most intimately, a fact illustrated by Fig. 18. This photograph was taken at the junction of body and glaze and shows the needle-like crystals of sillimanite penetrating into the glass. A hard porcelain of this type would consist of about 55 per cent. of clay substance (kaolin plus ball clay), 26 per cent. feldspar, and 19 per cent. of ground quartz (flint). A glaze for this kind of body would consist of 167.4 parts (by weight) of feldspar, 55 whiting (calcium carbonate), 21.6 magnesium carbonate, 64.5 kaolin and 282.0 of ground quartz.

As far as toughness and sturdiness is concerned the American vitreous porcelain is very satisfactory. Its only defect is the greater softness of the glaze which is not so resistant to abrasive and solvent action as the European type. This could be overcome to a considerable extent by raising the biscuit firing temperature to about cone 11 or 12 (1350 to 1370° C.) and likewise increasing the glost temperature to cone 5–6, 1230 to 1250° C. This would make possible the use of glazes free from lead oxide, though not from boric acid and the glazes thus produced should answer all requirements. Such a change would not necessitate any such far-reaching modifications of the manufacturing process as would be involved if the European hard porcelain process were adopted.

Hard fired porcelain proper is being manufactured in the United States to a limited extent by makers of chemical porcelain. There is no reason why the demand for this kind of product should not be entirely supplied at home. The technic is more difficult of course owing to the high-burning temperature and more precautions must be taken to prevent warping and deformation by the use of special supports and devices. Still there is no doubt but that potteries now producing hard chemical porcelain will soon begin the manufacture of table ware made from the same material. It must be supposed therefore that a considerable production of hard fire porcelain is to be expected in the United States within the near future.

FIG. 18.



Micro-section, showing junction of body and glaze with sillimanite crystals growing into glaze. German porcelain.

Refractory (Marquardt) porcelain, hitherto made only by the Royal Porcelain Manufactory (Berlin), is also being produced in this country, its manufacture having been introduced by the Pittsburgh laboratory of the Bureau of Standards.

Porcelain for electrical purposes and of excellent quality is being manufactured in the United States in large quantities. Its general composition corresponds to a mixture of 50 per cent. of kaolin and ball clay, 30 per cent. of feldspar and 20 per cent. of ground quartz. Electrical porcelain is fired to a temperature corresponding to pyrometric cone No. 10, or about 1330° C. Probably no kind of clay product is subjected to such severe service as high tension porcelain. It must hence be free from mechanical defects and must show perfect vitrification. Before leaving the factory the porcelain is subjected to exacting electrical tests. European electrical porcelain is fired to a higher temperature, cone 14–15, but it has not yet been established that the foreign material is superior to the American, though this claim has been made repeatedly.

The requirements of modern conditions have created a large and growing branch of the porcelain industry which specializes in the manufacture of sanitary ware of all kinds. The body used in this type of product is a true porcelain, showing practically no absorption. For larger pieces, such as bath-tubs a porous fire-clay body is employed more frequently, covered with a porcelain engobe and a glaze, finished in one fire.

The subject of pottery cannot be dismissed without referring to modern American achievements in art ware. The pioneer in this field has undoubtedly been the Rookwood pottery at Cincinnati, which has received world-wide recognition for its characteristic and beautiful underglaze decoration and the versatile development of a series of technics which have been imitated far and wide. Beautiful porcelain is being produced in Trenton (Lennox) and the decorative treatment of our commercial porcelain is undergoing steady improvement. A considerable number of large and small potteries and individual artists are steadily adding to the production of truly beautiful ceramic ware. Much is still to be accomplished and with increasing appreciation of the artistic handicrafts, there is every reason to believe that a still more vigorous development in ceramic art is to be expected.

The several American pottery industries manufacturing white products, whether these be porcelain or whiteware, are confronted by two important questions. One of these is the supply of domestic kaolin of high grade, corresponding in quality to the well-known English china clay. This is probably one of the most serious problems with which we have to deal. At the present time, contrary to the statement of publicists, there is no American kaolin which is the equivalent of the best grade of the English. It is true that ware of excellent whiteness can be made of a mixture of the washed North Carolina kaolins and secondary kaolins like those from Georgia and Florida, but it is likewise true that the winning and preparation of the Appalachian kaolinitic raw materials represent by no means a stable mining industry and source of supply. If we could count upon securing a sufficiently large volume of North Carolina kaolin in its purest form, the whole situation would be different, and there would be no question as to the kaolin situation. Unfortunately, not only is the crude weathered rock, which is the source of the kaolin, extremely variable in its yield and the content of impurities like quartz, feldspar and especially of mica reach very high proportions, but the methods of washing, in part due to lack of centralization and lack of capital, are frequently of a very primitive character and lacking entirely in technical control. Other known deposits of primary kaolin as those of Delaware, Connecticut, Maryland, Virginia, Pennsylvania, Wisconsin, Colorado, California, etc., are not sufficiently extensive or are lacking in whiteness. Definite information is lacking regarding many occurrences. It is to be regretted that no comprehensive survey has as yet been made of the kaolin resources of the United States. If concerted action had been taken by the users of these clays, there is no doubt but that it would have located deposits of kaolin which by proper mixing could be made to serve every purpose.

The other important economic question relates to the more efficient utilization of fuel in the manufacture of pottery and allied products. If we stop to consider that never more than 5 per cent. of the heating value of the coal is utilized in actually bringing the ware to the required temperature in the type of periodic kiln in use to-day, it seems inevitable that in the very near future far-reaching advances must be made. The type of kiln most promising for this, as well as other clay industries, dealing with comparatively small units, is the tunnel kiln. There are available in this connection the Faugeron or the Didier-March kiln already discussed in connection with the burning of brick and the Dressler kiln, an English invention. The latter is particularly promising for firing glazed products since it makes unnecessary the use of saggers, fire-clay boxes employed for the purpose of protecting the ware from ashes and impinging flames. Its construction is unusual and revolutionary, since the kiln charge is heated principally by convection through air currents heated by coming in contact with longitudinal heating or combustion chambers located on each side of the tunnel, as illustrated in the diagram of Fig. 19. Here the heated air, having been raised to a high temperature, by coming in contact with the surface of the combustion chamber, rises to the height of the tunnel, and being cooled upon coming in contact with the ware it descends to be again heated and continues its cycle. Radiation also comes into play, but the use of double-walled pieces in the construction of the heating chamber, illustrated in the diagram, which provide rapid circulation over the hot surface, is quite effective in screening it from the ware, since the outside shell is not very much hotter than the ware itself.

FIG. 19.

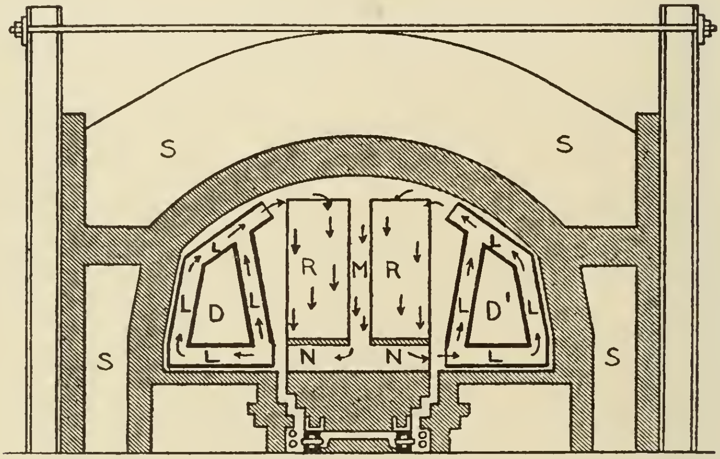
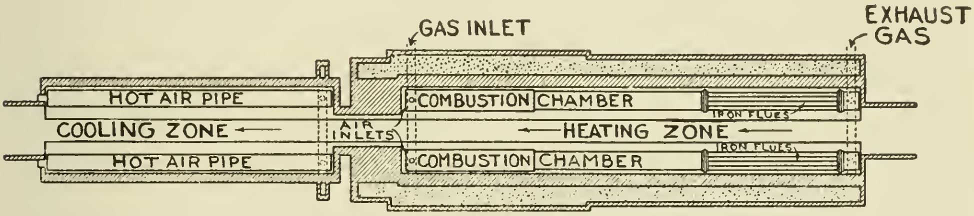


Diagram showing construction of Dressler kiln through the hot zone; D, combustion chambers R, ware to be fired; L, M, N, air passages.

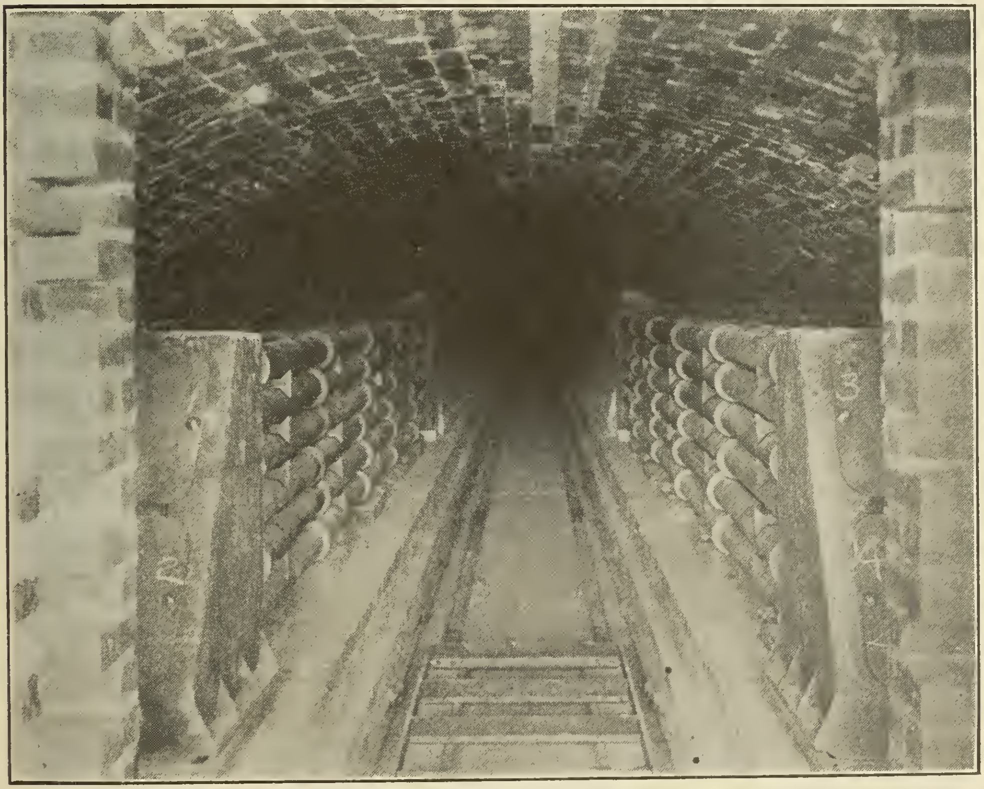
The continuous kiln principle requires that the heat of the finished ware be utilized in preheating the air used in combustion, or in doing other useful work. In the Dressler kiln this is accomplished by reversing in the cooling zone the cycle maintained in the heating zone. Here the finished ware furnishes the heat, imparting it to pipes which conduct the air needed for combustion. The ground plan of this kiln is shown in the diagram of Fig. 20. This kiln is capable of firing clay products with a coal consumption of from 5 to 12 per cent. of the weight of the ware. It is admirably suited for firing glazed ware, and there is no doubt but that it will find extensive application not only in the ceramic but also in the metallurgical and other industries. The kiln is capable of being controlled with ease. It requires gaseous fuel, in the form of producer or natural gas, though it may be adapted also to oil firing. The photograph of Fig. 21 shows the interior of the tunnel.

FIG. 20.



Plan of Dressler kiln.

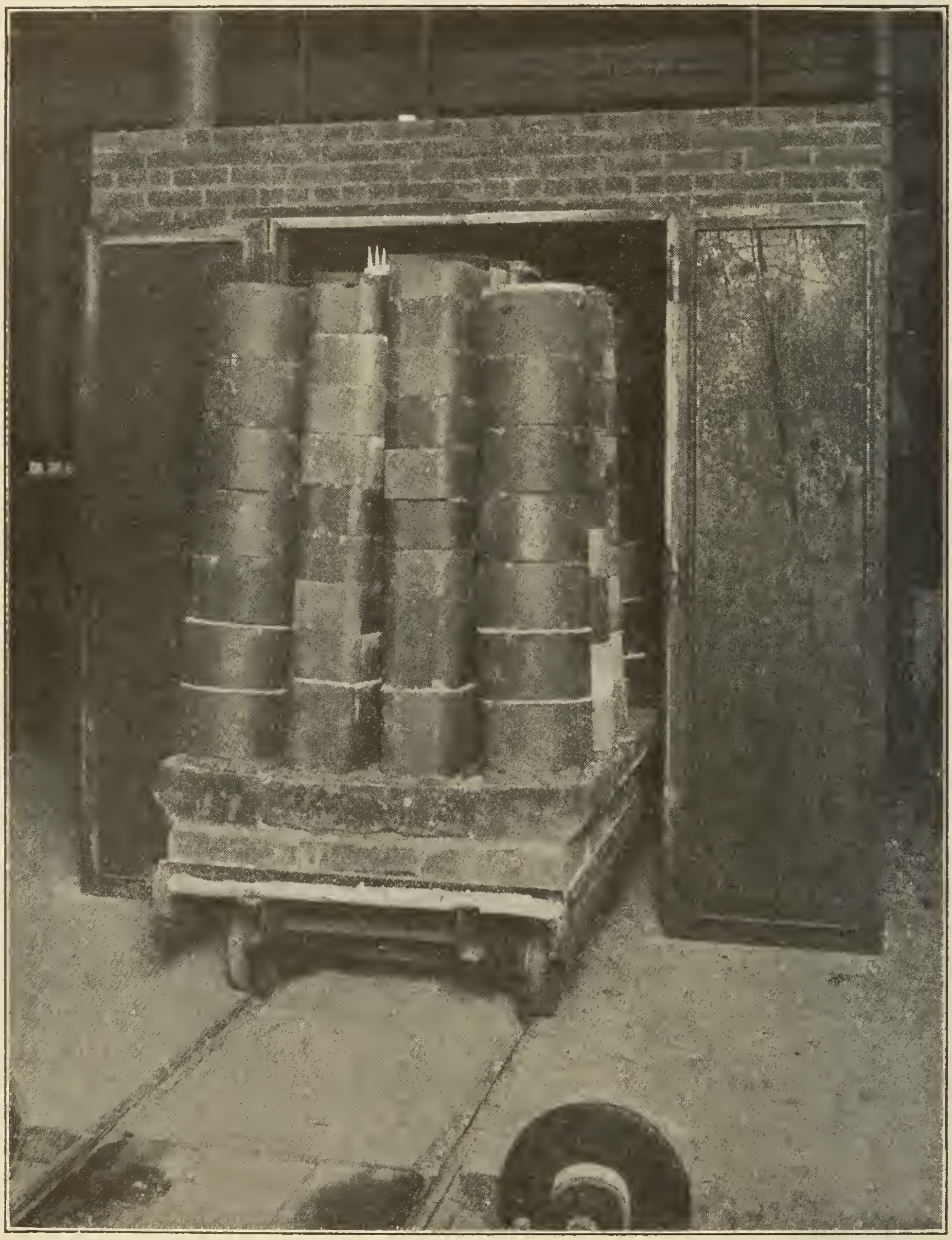
FIG. 21.



View showing interior of Dressler tunnel kiln.

The temperature which can be reached in this kiln is limited only by the refractoriness of the material from which the heating chamber is constructed. The ware entering the kiln is heated promptly by the use of iron heating pipes through which the cooled products of combustion are conducted.

FIG. 22.



View showing use of Didier-March tunnel kiln for burning porcelain. Car entering kiln.

The application of the Didier-March kiln to the firing of pottery is illustrated in the photograph of Fig. 22.

In addition to improving the firing process in the pottery industries, the mechanical side of the shaping process is now being developed in line with the modern ideas of efficiency, making it possible to save time in every manipulation. Thus, it has been proposed to construct revolving tables carrying a number of molds so that each operator performs only one manipulation. The molds thus come to the jiggerer already containing the proper amount of clay body, requiring on his part only the operation of the jiggering tool. The molds are then raised ready to be removed. The automatic operation of such tables makes it possible to increase the production decidedly and hence to lower the cost of production accordingly. Also plans are under way to dry pottery in a continuous operation by conveying the ware on pallets through a drying chamber using chain carriers.

Thus, the American clay industries may be said to be in a state of continuous growth, and there is every reason to believe that they will assume an increasingly greater importance in our national industrial activity.

Nickel Silver. ANON. (*The Metal Industry,* vol. 14, No. 12, December, 1916.)—The name "nickel silver" naturally creates the impression that this light colored metal is an alloy of nickel and silver, particularly when employed for articles of tableware manufactured by the silversmith. It contains however no silver, and even of nickel there is not more than 25 per cent., the remaining components being copper and a less amount of zinc. Ductile nickel silver suitable for table ware should be composed of 60 copper, 25 nickel, and 20 zinc or thereabout.

Nickel is the component which gives the alloy its silver-like color and resistance to corrosion. With an increasing amount of nickel the melting point rises and the tendency to produce gases in the crucible increases likewise. Finally the greater the percentage of nickel, the harder the alloy. Copper is the most ductile component, and a high content of this metal is desirable if the metal is to be subjected to rolling, stamping, drawing or spinning operations.

The value of the zinc lies in its effect of lowering the melting point and counteracting the gas-forming tendency of the nickel in the crucible. To what an extent the presence of nickel imparts its color to the alloy may be realized by an inspection of the United States five-cent piece. These coins contain 25 per cent. of nickel and 75 per cent. of copper, yet they show no trace of the deep color of their large copper content.

31,000 Horse-Power Turbines. ANON. (*Engineering News*, vol. 76, No. 20, November 16, 1916.)—The three turbines built for the initial installation of the Tallassee Power Company, a subsidiary of the Aluminum Company of America, at its Yadkin River development in North Carolina are by far the largest single-runner Francis turbines yet built. The remarkably steady load to be furnished by the nearby aluminum works permits of an efficient use of very large generating units, larger than is commonly desirable in general practice. Each turbine will develop 27,000 horse-power at maximum efficiency and 31,000 horse-power at full gate. Each turbine drives an 18,000 kilovolt-ampère, 36-cycle, 1320-volt three-phase generator with its exciter on top.

The notable points of interest are the use of steel-plate scroll casing embedded in concrete and a scheme of dismantling the runner from below without disturbing the generator or disturbing much of the turbine itself. The runner diameter is 108 inches; the speed 154 revolutions per minute; and the head, 165 to 180 feet. The casing inlet is 12 feet in diameter, and a tapering thimble connects to 15-foot penstocks. The upper part of the draft tube is of cast iron and telescopes into the section below, which is moulded in the concrete substructure. The draft tube is 11 feet in diameter at the top, but immediately begins to flare; and it flattens as it makes the usual right angle turn, the outlet being 32 feet wide and 13 feet 3 inches high.

Do the "Red Beds" of Wyoming Contain Potash Salts? ANON. (*U. S. Geological Survey Press Bulletin* No. 297, November, 1916.)—The Embar formation of Wyoming is known chiefly for its extensive phosphate beds, which are supposed to have been derived in some manner from animal remains. The rocks contain abundant fossils, many of which are phosphatic, and all of which prove that the Embar beds of western Wyoming were deposited in the sea. Recent study of the eastward extension of the Embar formation in Wyoming shows that along the east margin of this ancient sea, or throughout the Bighorn Mountain region, the climate was probably more arid than that of any part of Wyoming to-day. By long evaporation beds of gypsum were deposited at some places in arms of this sea to a thickness as great as 100 feet. It is a question of practical importance whether beds of salt, and perhaps of potash salt, may also have been deposited in this formation and whether they may now be found below the surface. The United States Geological Survey, Department of the Interior, urges that oil men, in drilling through the Chugwater and Embar red beds in Wyoming collect samples of drillings and of brines and submit them to the Survey for examination as to their possible potash content.

A paper by D. Dale Condit, describing the relations of the Embar and Chugwater formations in central Wyoming, and designated professional Paper 98-O, may be obtained on application to the Director of the U. S. Geological Survey.

THE ORGANIC NITROGEN COMPOUNDS OF SOILS AND FERTILIZERS.*

BY

ELBERT C. LATHROP, Ph.D.

INTRODUCTION.

THE present paper is a contribution to our knowledge of the chemistry of the nitrogenous portion of the soil organic matter. The investigations set forth were undertaken with a view to determine the chemistry of such nitrogenous soil compounds; to establish their distribution in agricultural soils; to define their origin and the biochemical changes which they undergo in the soil; and finally, to interpret the action and availability of the nitrogen of soils, peats and organic fertilizers.

Organic matter is that feature which distinguishes an agricultural soil from sand or powdered rock. Although it has been recognized for a number of centuries that the presence of organic matter in soil was a necessity for agriculture, it was not until the closing years of the eighteenth century that stress was laid upon the importance of this material in its relation to crop production. One of the most prominent writers of that day, the Earl of Dundonald, considered the organic matter of the soil to be the chief factor in crop production. While later investigators have shown that organic matter is by no means the only factor to be considered in soil fertility, they have demonstrated that it is of decided importance, not only from the chemical viewpoint but from the physical and biological as well. It has in fact become an axiom that any system of agriculture which tends permanently to decrease the organic matter of the soil is neither scientific nor profitable.

Although many investigations concerned with the chemical nature of the organic matter of soils have been made, it may be said that it is only within the last decade that this complex problem has begun to be solved. The lack of progress in this field of research has been due in no small measure to the fact that the biochemistry of the products of plants and animals, which eventually go to form the organic substances of soils by processes of decay, was itself so imperfectly understood. A contributing cause probably lay also in the fact that, while organic matter, or humus of soils, was known empirically to be of agricultural value, the investigations as to its more exact chemical nature were considered to be of greater theoretical than practical importance as compared to other soil studies, and therefore investigations concerning the nature of humus were often of a purely incidental nature.

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* Contribution from the Laboratory of Soil Fertility Investigations, communicated by Dr. Oswald Schreiner and published by permission of the Secretary of Agriculture.

The impelling necessity of learning more exactly the chemical and biochemical character of soil organic matter came with the observation that the infertility of certain soils could be explained only on the ground that they contained substances which were deleterious to plant growth. Experiments with aqueous extracts of these soils showed that these deleterious substances must be of an organic nature, and it was further demonstrated by Schreiner and Reed (1907)* that organic compounds likely to occur in soils were toxic in small amounts. Proceeding on this theory Schreiner and Shorey in 1908 succeeded in isolating from an infertile soil an organic hydroxy-acid, dihydroxystearic acid, which proved to be toxic in low concentrations to wheat seedlings grown in water culture solutions. At the same time they isolated three other compounds from soils: One was a nitrogen compound related to pyridine, picoline carboxylic acid by name, previously isolated from a Hawaiian soil by Shorey (1906), which proved to be only slightly toxic to wheat seedlings in water culture solutions; the other two were an acid and an alcohol, respectively, previously undescribed in the literature. These were without effect on plant growth.

The isolation from infertile soils of these two harmful organic substances furnished the material proof that certain soils may be infertile, not on account of the lack of any essential elements, such as potash, phosphorus, or nitrogen, but because of the presence of organic compounds in the soils, detrimental to the normal growth of crops. This idea, really a very old one, has met in the past with much favor and also with much criticism. It was advanced as a working hypothesis, because the idea seemed logical and right, but was discarded because no adequate proof of its validity could be furnished, due to the undeveloped state of science at the time.

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* For reference see Bibliography under name and date.

With this new proof of an old theory many questions arose which concern both practical and theoretical agriculture in respect to soil fertility. The whole question of soil humus, the process of humification, was opened up anew. Could not beneficial compounds in soils as well as toxic and neutral compounds exist? Were there not ways in which the decay of the organic matter of the soil might be controlled and directed, so that instead of producing poisonous compounds in the soil, neutral or even beneficial compounds would arise?

It is obvious that many procedures which are the every-day practice of the farmer, such as drainage, irrigation, mulching, inoculation with bacteria, addition of fertilizers and stable manures, etc., all exert more or less influence on the course of the chemical changes taking place in the soil. It is also equally obvious that there can be no intelligent chemical control of any process unless the chemical nature of the materials involved is thoroughly understood. It therefore became essential to make a systematic chemical and biochemical study of the organic matter of soils. With no established facts and no methods of attack worked out, progress was necessarily slow at first, but gained speed with each compound isolated and identified, until now there have been isolated from soils about fifty definite organic compounds. An idea of the diverse chemical nature of these may be obtained from the fact that representatives of the following large classes of organic compounds have been isolated from soils: Acids of both the aromatic and aliphatic series, higher alcohols, aldehydes, hydrocarbons, carbohydrates, resins, esters, glycerides, glucosides, amino acids, nucleic acids, proteoses and peptones, amines, purine bases, pyrimidine bases, various other nitrogen and sulfur containing compounds, etc. These compounds may be considered to cover fairly well the principal classes of compounds encountered in other lines of biochemistry, and therefore the knowledge in regard to the chemical relationships, origin and processes of change accumulated in such other lines can be directly applied to the understanding of the biochemical changes in soils and the constitution of soil organic matter. Thus it has been possible to throw much light upon the biological and biochemical changes in soils so that the old views of soil organic matter, soil humus and the process of humification have been either radically modified or completely overthrown.

These compounds, isolated from soils, have been tested in regard to their effects on plant growth. In water culture solution experiments, and in several cases in pot and field tests as well, some of these compounds have been found to be toxic, others neutral, and quite a few beneficial to plant growth. To this latter class of compounds belong many of the nitrogenous compounds found in soils. Indeed, some of these nitrogenous compounds seem to be utilized by the plants with such ease that they equal in nutritive value the nitrates themselves. It is chiefly with such nitrogenous compounds that the present investigation is concerned.

THE SOURCE OF NITROGENOUS MATERIALS IN SOILS.

The quantity of total nitrogen in soils varies from a few hundredths of a percentage in light sandy soils to five-tenths of a percentage or more in rich, heavy loams. Peats and mucks, which from an agricultural viewpoint will be considered as soils high in organic matter in this paper, contain from five-tenths of a percentage of total nitrogen in the case of light mucks to about four per cent. in the case of some peats. Of the total nitrogen in soils, normally only about one-tenth of a percentage exists in the form of ammonia or ammonium salts and about one to two per cent. in the form of nitrates. The remaining portion of the total nitrogen, ninety-seven to ninety-nine per cent., exists in organic combination.

In view of the fact that the ultimate source of the organic constituents found in soils is the débris of plants or animals and that organic nitrogenous compounds are a constituent part of all protoplasm, a comprehensive conception of the more immediate sources of the nitrogenous matter of soils may best be obtained by a consideration of the sources of soil organic matter in general. The organic matter of soils may be divided into two general classes: living and non-living. To the former class belong earthworms, beetles, larvæ, molds, yeasts, bacteria, protozoa, higher fungi, algæ, roots and rootlets of the higher plants. The greater portion of the organic matter consists, however, of non-living matter.

This organic matter may be conveniently subdivided into four classes:

(1) The materials furnished by the recent generations of

living matter in the soil, or by recent additions of organic manures, fertilizers, or plant débris, and other extraneous matter, which has not yet been in the soil for a long enough time to decompose and still retains to a very great extent the physical structure of its former self. However, chemical changes incident to the death of the plant and animal cells have already occurred in this material, such, for example, as those brought about by the interaction of soluble compounds, non-reactive in the living cell, or by autolysis due to the enzymotic action within the dead cell. These processes may produce both lysis and synthesis and are probably of considerable importance in the transformation of organized material into humus.

(2) Material which has either partially or wholly lost all vestige of its original structure. Such substances have already undergone considerable chemical change either by direct oxidation or reduction, or by chemical changes produced either by the organisms of the soil, or by other agencies. To this class of organic soil material belong all compounds intermediate between the complex organic substances which composed the original plant or animal materials entering the soil and the final products of their decay. This class makes up the major portion of the organic matter of ordinary agricultural soils.

(3) Substances which decompose only very slowly in the soil or not at all. In this connection it is interesting to note that Schreiner and Brown (1912), in investigating this resistant class of organic material, discovered in many soils particles of coal. lignite, charcoal, remains of insects, resins, etc. There is also some evidence that to this class of more or less organized substances there should be added certain very complex chemical compounds such as those obtained synthetically by Maillard (1913) through the interaction of certain carbohydrates and amino acids, compounds which seem to be resistant to chemical treatment.

(4) The synthetic products of the life processes of the microorganisms in the soil, both those that fix atmospheric nitrogen and those that synthesize into more complex compounds, such as proteins and nucleoproteins, the nitrogen which is present in the soil in the simpler forms of ammonia, nitrates, amides or amino compounds.

CONDITIONS CONTRIBUTING TO THE CHANGES IN SOIL ORGANIC MATTER.

The organic matter of soils must be considered to be material in a dynamic state. It is not only the product of change, but at the same time it is continually in a state of change. Two processes are continually going on in soils, one which is essentially lysis, the breaking down of the complex compounds into the simpler by the processes of hydrolysis, oxidation, reduction, etc., and the other synthesis, or the building up of complex compounds from the simpler ones.

The factors which are operative in these changes constantly taking place in the soil are many and varied. Possibly the most important are the microörganisms of the soil, which find the organic matter a favorable medium for growth. No fact, however, concerning microörganisms is probably better established than that they are profoundly influenced by the nature of the medium, not only in their habits of growth but also in the products which they produce. Such factors as moisture, aeration, acidity or alkalinity, the nature of the organic matter, the mineral constituents of the soil, the addition of fertilizers, etc., will, therefore, exert a marked influence, not only on the types of the active microörganisms, but also on the nature of the changes which they produce in the soil.

At the same time these various factors influence also the purely chemical changes taking place in the soil. That is, the course of the decomposition will be different according to the factors concerned in the decay. When certain conditions predominate, the compounds produced in the soil will be normal and beneficial. If, however, another set of conditions prevails, the compounds may be abnormal and harmful. In soils there is a balance of the beneficial and harmful factors, soil fertility or infertility being the resultant of the two groups. As one or the other of the groups gains ascendency, the fertility is raised or lowered, as the case may be.

PREVIOUS INVESTIGATIONS.

Among the first investigators to study the organic matter of soils may be mentioned Einhof (1805), Braconnot (1819), Mitscherlich, Sprengel (1826), Boullay (1830), Klaproth (1833), Malguti (1835), Thompson (1840) and Mulder (1840–1862). Of these investigators Mulder is the most quoted and his work and ideas in regard to the chemical nature of the organic matter of soil had in a large measure held sway until the close of the last century.

The investigations of these early workers naturally appear somewhat crude in the light of today. The organic chemistry known to them was essentially a determination of elementary composition and most methods utilized at the present time for the isolation of organic compounds were unknown, as were most of the compounds involved. The organic compounds of the soils they considered to be acids of high carbon, hydrogen, and oxygen content, and these but few in number.

Nitrogen was considered to be present in the humus of soils as an ammonium salt of the "humic acids." In this regard Mulder states:

"In a good arable soil—that is, one in which the organic constituents are as far as possible decomposed—none of these substances (the humic acids) contain nitrogen as a constituent element; all of their nitrogen exists in the state of ammonia." Mulder, however, seemed to believe that the plant albumins were the original source of the nitrogen of soil.

Detmer (1871) did not come to this conclusion at first, although later he seems to have taken Mulder's view. He claimed that the nitrogen in the soil was in organic combinations, basing his conclusions on the facts that the humic acid, when treated with potassium hydroxide, gave off no ammonia and that about 21 per cent. of the total nitrogen was liberated on treatment with alkaline hypobromate. This is the first indication of the existence of organic nitrogen compounds in soils.

Simon (1875) claimed that peat absorbed nitrogen from the air with the formation of ammonium compounds, a claim which was later disproved.

Ritthausen (1880) thought that the high nitrogen content of peat was due to the absorption of ammonia with the formation of complex, difficultly decomposable compounds.

v. Sivers (1880) found that only a small amount of the nitrogen of peat could be driven off as ammonia on heating with potassium hydroxide and, although he offered no material evidence, he considered the nitrogen of peat to be present largely in protein form.

Grouven (1883) found in various samples of peat that only one-fifth of the nitrogen was driven off when heated with milk of lime for several hours, and only one-twentieth when heated with potassium hydroxide for two hours.

Loges (1886) found that a hydrochloric acid extract of a soil gave a precipitate with phosphotungstic acid, which is generally recognized as a precipitant for basic nitrogenous compounds.

Up to this time, aside from Detmer's experiments, the significance of which was apparently overlooked, nothing definite had been determined in respect to the form in which nitrogen existed in soils and peats excepting that a small amount was present as ammonia.

In 1886 Berthelot and André concluded that the nitrogen in the soils they studied was not present as ammonia, but in organic form, partly as amides.

A. Baumann in the following year suggested the presence of amide compounds in the soil, since he obtained, on boiling the soils with hydrochloric acid, ammonia, which was not originally present in the soil.

Eggertz (1889) found that the nitrogen content of thirteen samples of humus varied from 2.5 to 6.4 per cent. and states that the nitrogen was present in organic form and not as ammonia.

Warington (1887) at Rothamsted demonstrated the presence of small amounts of soluble amides in soils which had been heavily manured.

Sestini (1899) contradicted the idea that any great amount of amides could be present in soils and reports that a portion of the nitrogen was present in the form of amino acids.

Dojarenko (1901–1902) obtained large amounts of amino nitrogen from the black soils of Russia. He was the first to make a quantitative study, applying the method of Sachsse and Kormann as modified by Boehmer (1883). He found that from 21 to 71 per cent. of the total nitrogen of the "humic acid" was present in the form of amino compounds, from 5 to 20 per cent. in amido form and as much as 2 per cent. in the form of ammonia.

Shorey (1905) with a view to classifying the nitrogenous compounds, applied the method of Hausmann (1899) modified by Osborne and Harris (1903) to the study of Hawaiian soils. He obtained in the acid solution 78 per cent. of the total nitrogen in the soil, more than half of which existed as "humin" nitrogen, and the remainder as ammonia, diamino acids, and monoamino acids.

None of the investigators so far considered dealt with the isolation and identification of any definite organic nitrogenous compounds from soils. They merely attempted to classify the nitrogenous portion of the organic matter. The net results indicate that the soil contains either amides or amino acids or else compounds, which on heating with strong alkalies or acids, decompose, giving reactions for amides or amino acids. Such evidence would suggest that the nitrogen of the soil arises largely from protein materials and probably contains proteins.

It remained for Shorey in 1906 to isolate the first definite organic compound from soils. Considering the preceding investigations, it is rather surprising that the compound was not a primary decomposition product of proteins, but was a pyridine derivative, picoline carboxylic acid. Berthelot and André had in 1891, however, obtained results on the distillation of soils which suggested to them the presence of a pyridine compound. The presence of this compound in the Takoma soil was later reported by Schreiner and Shorey (1909), who suggest that this acid, which is slightly toxic to wheat seedlings, probably arises from the secondary decomposition of proteins in the soil.

The investigations dating from 1906 may be divided into two classes (1), those dealing with analytical methods with the view to classifying the forms in which the soil nitrogen occurs, and (2), those dealing with the actual isolation and identification of organic nitrogenous compounds from soils.

To the first class belong the extended investigations of Jodidi (1909, 1911) on peats of Michigan and soils of Iowa. He hydrolysed the peats with strong mineral acids and determined the forms of nitrogen by approximately the same method as that used by Shorey. He found that on hydrolysis about two-thirds to three-fourths of the nitrogen was in the form of monoamino acids, one-fourth in the form of amides and the rest in the form of diamino acids. With the Iowa soils he went still further and with the method of Sörenson (1907) found that practically all of the nitrogen classed as diamino acid nitrogen existed in amino form, while from 40 to 92 per cent. of the monoamino acid nitrogen existed in amino acid forms. The amide nitrogen was found to be composed entirely of amides, since only ammonia was obtained when the acid extract was distilled with magnesia.

Lathrop and Brown (1911), by use of the Hausmann method as modified by Osborne and Harris, made a study of a soil located at the Pennsylvania State College Agricultural Experiment Station, which had been subjected to different manurial treatments in respect to nitrogen, and found that the forms of nitrogen in the different plats varied.

Working with the soils of Hawaii, Kelly and Thompson (1914) found that the amount of nitrogen dissolved by boiling with strong hydrochloric acid was from 67 to 92 per cent. of the total nitrogen, and that the relative percentages of amide and basic nitrogen split off during hydrolysis stand in the reverse order to that in which they occur in vegetable proteins.

Potter and Snyder (1915) report studies on Iowa soils both by the use of the Van Slyke method (1911) on the hydrolysis mixture from the soils and by the use of the Kober method (1913) on a 1 per cent. alkaline extract of the soils. They conclude that the amount of amino acid and peptide nitrogen existing free in the soil is very small when compared with the amount of amino acids found after hydrolysis of the soils with acids, and that the amount of amino nitrogen was less than the ammonia nitrogen.

Chardet (1914) reports experiments on soils in which he extracted the soils with 2 per cent. sodium hydroxide solution and, after suitable procedure, determined the amino nitrogen according to the method of Sörenson. He states that the amino acids represent from 49 to 68 per cent. of the total nitrogen.

Schmuk (1914), working with Russian soils according to the modified method of Hausmann, concludes that the nitrogen in the soil is of a protein nature.

Suzuki (1907) reports results obtained by hydrolysing humus, from three different sources, with strong hydrochloric acid. The acid solution was subjected to esterification and fractional distillation according to the method of Fischer (1901, i, ii) for the isolation and estimation of the amino acids. He obtained by this procedure, alanine, leucine, aminovaleric acid, proline, aspartic acid, glutamic acid, traces of histidine and tyrosine, together with some unidentified acids. Suzuki concludes that humus is made up largely of proteins. His conclusion seems, however, from his experiments not wholly to be warranted, since some of the amino acids which he found may have existed in that form in the humus and not have been differentiated by the method which he used.

Robinson (1911) succeeded in isolating both leucine and isoleucine from the acid solution resulting on the hydrolysis of Michigan peats with hydrochloric acid. He was also the first to subject peat to analysis by the Van Slyke method.

The investigations concerned with the isolation of definite organic nitrogenous compounds from soils have chiefly been conducted by Oswald Schreiner and his colleagues, Shorey, Lathrop, Walters, and Wise. These investigators have up to the present reported the following nitrogenous compounds in agricultural soils: The purine bases, xanthine, hypoxanthine, adenine and guanine; the pyrimidine base, cytosine; the hexone bases, histidine, arginine, and lysine; the pyridine derivative, picoline carboxylic acid; and the compounds, creatinine, choline, trimethylamine, tetracarbonimid, cyanuric acid, nucleic acids, proteoses and peptones. Fosse (1916) has recently added urea to this list of nitrogenous soil compounds, reporting it to have been found in forest, truck, humus, and virgin soils, in France.

The evidence obtained by all of these investigations leads to the conclusion that the larger portion of the nitrogenous organic matter normally present in soils consists of the primary or secondary decomposition products of protein and of protein itself. In this connection it is interesting to note that the organic nitrogenous fertilizing materials commonly added to soils also contain proteins or protein-like substances. From the strictly biochemical point of view, therefore, the changes taking place in the organic nitrogenous materials in the soil or in those added to the soil in the form of fertilizers, crop remains, etc., may be considered to be those of protein degradation.

THE PROTEIN MOLECULE.

The proteins are compounds of extremely high molecular weight, are generally in colloidal condition, and act as amphoteric electrolytes; facts of the greatest significance to biology. About 50 natural proteins are known and these are classified according to their origin and physical properties into a number of groups: Protamines, Histones, Albumins, Globulins, Glutelins, Gliadins, Phosphoproteins, Scleroproteins, and Conjugated proteins. In addition, a large number of protein-like compounds, called polypeptides, have been synthesized.

Investigations on the chemical structure of the proteins were begun at about the same time as the investigations on the nature of the organic nitrogenous matter of soils and the unravelling of the latter problem has progressed with the solution of the former. The synthetic researches of Emil Fischer (1899–1906) and his co-workers on the structure of the protein molecule prove the accuracy of Hofmeister's view (1902) that the protein molecule is built up of amino acids combined principally in the form of acid amides according to the following structure:

$$NH_2.CHR.CO\text{–}(NH.CHR.CO)_x\text{–}NH.CHR.COOH.$$

Fischer has termed the combinations of the amino acids which he prepared, polypeptides, and by the method of preparation the arrangements of the amino acids in them is known. The chemical nature of an albumin is partly determined by the quantitative relationships of the different amino acids and partly by the arrangements of these in the molecule.

Several points regarding the constitution of the protein molecule have been fairly conclusively established which have a direct bearing on the study of soil organic nitrogen. On acid hydrolysis a small portion of the total nitrogen of the protein is liberated as ammonia from the acid amide group ($CO\text{–}NH_2$) in the protein molecule. From a study of the amounts of ammonia formed by the hydrolysis of a large number of proteins by acids and the amounts of ammonia formed by heating these proteins with a solution of sodium hydroxide, Osborne, Leavenworth and Brautlecht (1908, ii) conclude that it is highly probable that the ammonia produced on acid hydrolysis results from an amide union ($\text{–}CO\text{–}NH_2$) in the protein molecule, and that the ammonia formed by treatment with alkali results from the disrupting of this union and from the destruction of arginine. By treatment with sodium hydroxide solution arginine is split into urea and ornithine and the urea is decomposed with the formation of ammonia. (E. Schultz, 1891, 1897, 1898.)

The greater portion of the nitrogen of proteins exists after hydrolysis in the form of NH_2 groups in amino acids. In the protein molecule, however, the greater part of the nitrogen is present, not in the form of the amino group (NH_2) but in anhydride linkages, in imino groups (NH), as is shown by the limited reaction of the proteins with nitrous acid. However, Van Slyke and Birchard (1913), from a study of the action of certain proteins towards nitrous acid, conclude that one of the two amino groups of lysine, the ω-group, exists free in the protein molecule. Almost the entire amount of free amino nitrogen determinable by the nitrous acid method in the native proteins is represented by this ω-group of lysine. The α-amino groups which constitute the remaining and greater part of the nitrogen found after hydrolysis, are, in the intact molecule, practically all condensed into peptide linkages. With primary albumoses, the first decomposition products of protein, the relations are different; the free amino nitrogen in hetero- and proto-albumoses exceeds half of the lysine nitrogen by 3.0 and 4.8 per cent. of the total nitrogen respectively, indicating that an appreciable portion of the α-amino groups of other amino acids is uncovered even in these complex primary digestion products.

PROTEIN HYDROLYSIS.

Hydrolysis of the protein molecule by means of acids, alkalies, moist heat or enzymotic processes results in the introduction of water into the molecule at various definite places, with the concurrent formation of albumoses, peptones, polypeptides, amino acids and ammonia, the amounts and nature of the products depending on the specific protein and the reagents used. Some proteins are easily hydrolysed, while others break down only under energetic and prolonged treatments. The ease with which proteins are hydrolysed is a matter of much practical significance to soil fertility, since it is intimately connected with the question of the availability of nitrogenous fertilizers, a subject which will be more fully discussed in another portion of this paper.

The extent of hydrolysis of proteins with acids or alkalies depends not only upon the strength of the reagent but also upon the length of treatment. For example, by means of hot dilute acid, or the action of more concentrated acid in the cold, complex polypeptides have been obtained as partial hydrolysis products. The action of moist heat is less energetic than that of chemical reagents, generally inducing changes of a milder order. The final products of hydrolysis are ammonia and the amino acids.

Hydrolysis by the proteoclastic enzymes is, however, never complete. With pepsin amino acids are said to be formed, only in small amount, the splitting of the protein resulting chiefly in the formation of albumoses, peptones, peptides and ammonia. It would seem, therefore, that pepsin is able to open up the anhydride ring of the protein at one or more junctures, but is not able easily to produce in this way free amino acids. The action of trypsin differs from that of pepsin, in that, although it cannot break down all proteins, requiring in many instances the action of pepsin first, it splits the protein more deeply, giving almost complete hydrolysis, with the formation of amino acids together with many of the products of peptic digestion. Trypsin and erepsin seem to be able to hydrolyse chains of amino acids with terminal carboxyl or amino groups, separating the imino group (NH) from the neighboring carboxyl, according to the general formula:

$$\underset{(1)}{CO} - NH - \underset{(2)}{C} \quad \text{becomes} \quad \underset{(1)}{COOH}, \quad NH_2 - \underset{(2)}{C}$$

Another type of splitting occurs in the action of arginase, which splits arginine into ornithine and urea:[1]

$$NH_2 . CNH . NH . C_3H_6 . CHNH_2 . COOH - H_2O =$$
$$NH_2 . CO_2 . NH_2 + NH_2 . C_3H_6CHNH_2 . COOH.$$

That even after prolonged action of trypsin on albumin, protein-like substances remain, and that all of the nitrogen present in the acid amide groups ($-CO-NH_2$) is not split off, have been shown by Fischer and Abderhalden (1903). After hydrolysis of an albumin with trypsin for several months these investigators obtained a polypeptide which on further hydrolysis with acids yielded glycocoll, alanine, leucine, proline, phenylalanine, aspartic acid, and glutamic acid. Since the polypeptide yielded the monoaminocarboxylic acids on hydrolysis, it follows that the hydrolytic formation of ammonia is not complete by such enzyme action.

SPLITTING OF PROTEINS BY MICROÖRGANISMS.

Numerous investigations concerning the action of microörganisms in the decomposition of protein materials have been carried on and the following general conclusions may be drawn from them. There is little reason to suppose that the action of microörganisms is other than that of the enzymes which they produce. Kruse (1910) states that the bacterial proteoclastic enzymes resemble pepsin, trypsin, and erepsin in the mode of their action, but are somewhat different from these. Dox (1910) finds that the proteoclastic enzymes of mold are the same in action as those occurring in plants and animals. In addition to the purely hydrolytic enzymes concerned with the splitting of the complex proteins into amino acids, etc., other specific enzymes seem to be present either as extra- or intracellular enzymes of the microorganisms found in the soil. The degradation of proteins by microörganisms, then, proceeds along the same general lines as that produced by the proteoclastic enzymes or acids, but does not stop with hydrolytic cleavage, a deeper change taking place, with the formation of secondary protein decomposition products, such as ammonia and carbon dioxide in large quantities, together with amines, fatty acids, alcohols, aldehydes, methane, phenol, skatole, indole, hydrogen sulfide, etc.

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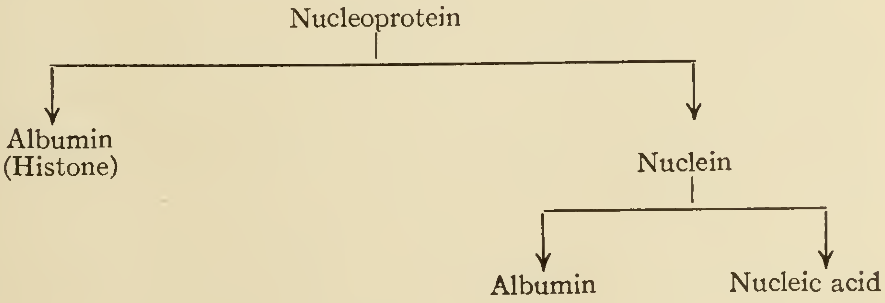
[1] See Kossel (1898); Kossel and Matthews (1898) and Kossel and Dakin (1904).

NUCLEOPROTEIN DEGRADATION.

Perhaps the most complex of the compounds which enter the soil are the nucleoproteins. They are the common constituents of all plants, animals, bacteria, molds, etc., and occur, therefore, wherever these live and die. It may be well to follow the compounds which are formed by the chemical changes incident to the decomposition of this class of protein material. Lilienfeld (1892) has expressed the decomposition of a nucleoprotein by the following schematic representation:



The products of decomposition then are albumin, or protein, and nucleic acid. Protein materials have been isolated from the soil by Walters (1915) of this laboratory.

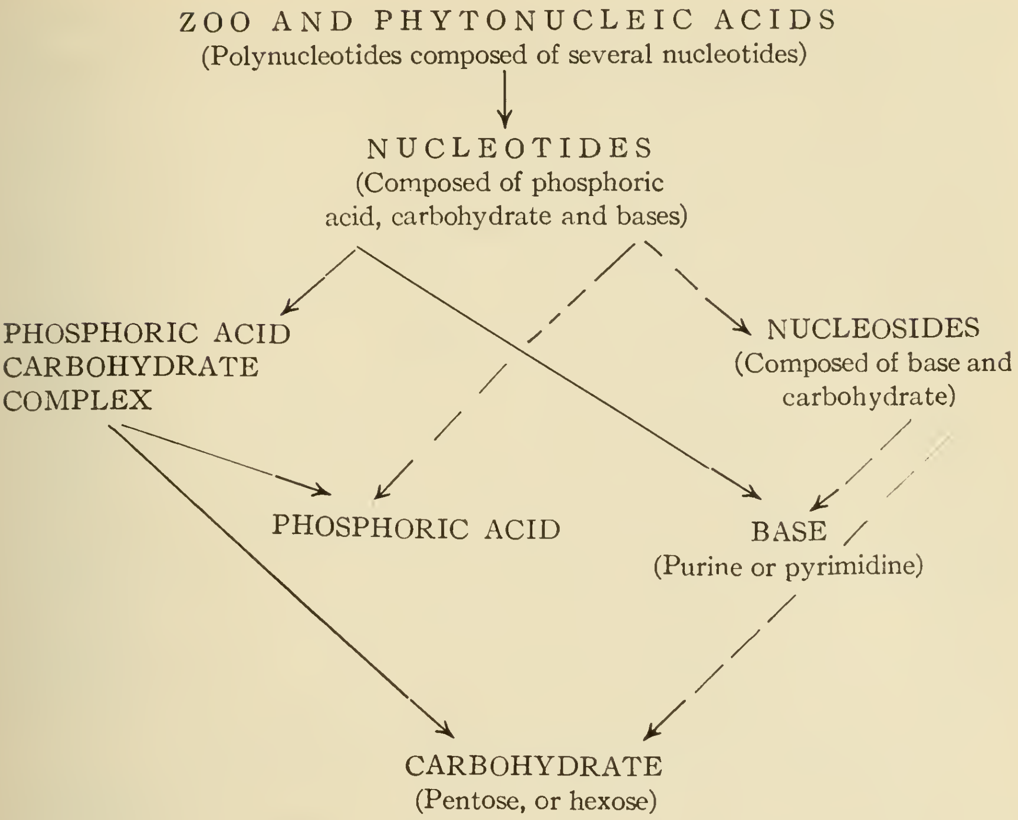
NUCLEIC ACID DEGRADATION.

Nucleic acid is a class name covering a large number of compounds, composed of carbon, hydrogen, oxygen, nitrogen, and phosphorus, occurring in plant and animal cells. Nucleic acids were isolated from soils by Shorey (1912, ii). They are very complex and yield on decomposition a number of compounds of less complex structure.

The proportion of the five elements in nucleic acids differs, depending upon the source of the acids, and this is due to the fact that the unit substances composing them are different. Thus, for instance, the nucleic acid from yeast, according to Herlant (1900), has the composition $C_{36}H_{48}O_{30}N_{14}P_4$; that from salmon, according to Schmiedeberg (1899), the composition $C_{40}H_{52}O_{25}N_{14}P_4$; and that from wheat, according to Osborne and Harris (1902), the composition $C_{41}H_{61}O_{31}N_{16}P_4$. Many hold the view that there are but two nucleic acids in nature, one the nucleic acid of the plant and the other the nucleic acid of the animal cells.

The constitution of these complex nucleic acids is not fully known, but the constitution of most of the dissociation products is known. As above mentioned, the dissociation products vary with the source of the acid. The hydrolytic products of the nucleic acid of plant origin are: Phosphoric acid, guanine, adenine, cytosine, uracil and pentose. The hydrolytic products of nucleic acid of animal origin are: Phosphoric acid, guanine, adenine, cytosine, thymine and lævulinic acid. The lævulinic acid is formed from a hexose group in the molecule of the nucleic acid.

While the simple end-products of the nucleic acids are those mentioned, the dissolution of the nucleic acid molecule does not take place in one step. There are several intermediary products or combinations of the above mentioned final products which have definite chemical and physical identity. The researches of Levene and of Jones have served to clear up to a large extent the nature of these intermediary products. The steps in the disintegration of the plant and animal nucleic acids can perhaps best be made clear by the following schematic representations:


ZOO AND PHYTONUCLEIC ACIDS
(Polynucleotides composed of several nucleotides)
NUCLEOTIDES
(Composed of phosphoric acid, carbohydrate and bases)
PHOSPHORIC ACID CARBOHYDRATE COMPLEX
NUCLEOSIDES
(Composed of base and carbohydrate)
PHOSPHORIC ACID
BASE
(Purine or pyrimidine)
CARBOHYDRATE
(Pentose, or hexose)

The complex zoo or phytonucleic acids, for instance, those from wheat, yeast, salmon, are composed of simpler nucleic acids, which Levene has called nucleotides. The nucleotides are composed of phosphoric acid, carbohydrates, and bases, either purine or pyrimidine. Several of these nucleotides have been isolated, for example, guanilic acid (Levene and Jacobs, 1910), inosinic acid (Levene and Jacobs, 1911), cytidin-phosphoric acid (Levene, 1911), uridin-phosphoric acid (Levene, 1911), thymohexose-phosphoric acid (Levene, 1910). On further decomposition the nucleotide can part with its phosphoric acid on the one hand and yield a complex consisting of the base and the carbohydrate, designated as a nucleoside in the diagram, and on the other hand it can part with the base and leave a complex consisting of phosphoric acid and carbohydrate. Of the nucleosides a considerable number are known, guanosin, inosin, adenosin (Levene, 1910), and xanthosin (Levene, 1911), which are respectively guanine, hypoxanthine, adenine and xanthine combined with the carbohydrate. Further, from the nucleotides cytidin- and uridin-phosphoric acids, the nucleosides cytidin and uridin (Levene,

1911) are obtained, which consist, respectively, of combinations of cytosine and uracil with carbohydrates. Several of these compounds form well-defined crystalline bodies and form salts of the same type as the base contained in them. A definite carbohydrate-phosphoric acid complex has also been isolated and a crystalline barium salt obtained. This is the d-ribose phosphoric acid obtained by Levene and Jacobs (1908). All of these various products can then be broken down into phosphoric acid, carbohydrate, and base, purine or pyrimidine.

TRANSFORMATION OF THE BASES.

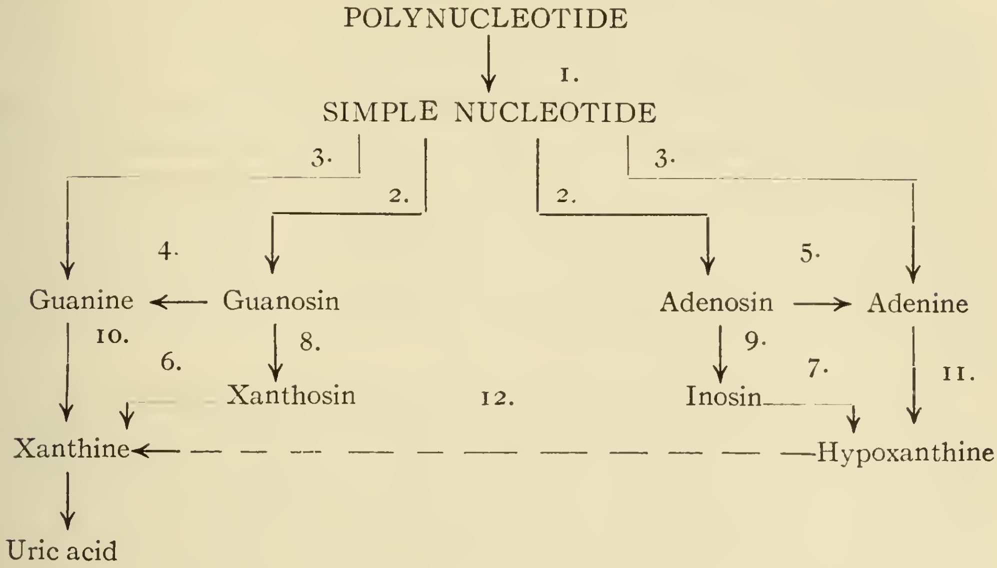
The purine and also the pyrimidine derivatives are capable of being changed one into the other, by both chemical and biochemical agencies. Nitrous acid has been used to effect such changes. Fischer (1882) changed guanine into xanthine, Kossel (1886) changed adenine into hypoxanthine, and Kossel and Steudel (1903) changed cytosine into uracil. Similarly Levene (1911) has changed the complexes guanosin, adenosin, and cytidin into xanthosin, inosin and uridin, respectively.

These changes produced by strictly chemical means are paralleled by the biochemical changes induced by bacteria and enzymes. It was shown by Schittenhelm and Schröter (1904) that putrefactive bacteria, especially coli bacillus, were able to convert adenine and guanine into hypoxanthine and xanthine. They also show that the bacteria have the power of splitting down the nucleic acid itself. This change of nucleic acids is brought about also by certain enzymes which have been called nucleases, such as erepsin. (Nakayama, 1904; Iwanoff, 1903; Sachs, 1905.)

Schittenhelm (1909) has shown that there is present in the pressed juice of lupine seeds an amidase capable of converting guanine into xanthine. Burian (1905) showed that enzymes were capable of oxidizing xanthine and hypoxanthine into uric acid. The existence of amidases capable of causing the conversion of the amido purines (guanine and adenine) into the oxypurines (xanthine and hypoxanthine) has been repeatedly demonstrated.

According to Levene and Medigrecaenu (1911, i, ii, iii) nucleic acids are not decomposed by any one ferment. Levene and LaForge (1912) have shown that in some nucleic acids the pyrimidine complex is very resistant to the hydrolytic action of dilute acids and of enzymes.

The changes induced by these various enzymes may perhaps best be shown by the diagram given by Amberg and Jones (1911):



ENZYMES WHICH PRODUCE THE VARIOUS CHANGES.

1. Nuclease
2. Phosphonuclease } Nucleotidases.
3. Purinenuclease }
4. Guanosinhydrolase }
5. Adenosinhydrolase } Nucleosidases.
6. Xanthosinhydrolase }
7. Inosinhydrolase }
8. Guanosindesamidase
9. Adenosindesamidase
10. Guanase } Purindesamidases.
11. Adenase }
12. Xanthinoxydase

The above exposition of the changes involved in the degradation of the nucleoproteins makes clear the fact that this operation takes place in many stages, and also that many of the intermediary, as well as the final products, are capable of being transformed the one into the other. This degradation can be brought about in many ways: By chemical means, such as the action of acids, alkalies, and steam under pressure; by microörganisms; and also by the enzymes of plants and animals.

THE PRODUCTION OF AMMONIA IN SOILS DUE CHIEFLY TO THE SECONDARY DECOMPOSITION OF PROTEINS.

Under natural conditions the changing of organic nitrogen into ammonia is the work of microörganisms in the soil. Müntz and Coudon (1893), studying the ammonification in sterilized and unsterilized soil showed that during two and one-half years there was no ammonia formation in the sterilized soil while the unsterilized soil in sixty-seven days produced from 41 to 100 milligrams of ammonia per 100 grams of soil. The investigations concerned with the process of ammonification cover a large number of years and a résumé of this work is not deemed essential here.

As has already been shown, when the protein material is hydrolysed a small amount of ammonia is formed due to the breaking down of the acid amide ($-CO-NH_2$) linkages of the protein molecule. The amount of ammonia thus produced is about 4 to 9 per cent. of the total nitrogen of the proteins. Repeated experiments have shown that the amount of ammonia produced during the decomposition of protein matter in the soil far exceeds these small amounts. For example in the experiment on the decomposition of dried blood, described in another portion of this paper, if ammonia were formed only from the splitting off of the amide group from the proteins of the dried blood the total amount of the ammonia formed during the course of the decomposition would be about 7 per cent. However, about 75 per cent. of the total nitrogen of the proteins was changed to ammonia during this decomposition. It is evident, therefore, that ammonia must be formed from other fractions of the protein molecule besides that containing the amide linkage. Experiments have shown that the greater part of the ammonia produced during the decay of protein material in the soil arises through what is known as the process of secondary decomposition.

In regard to the action of microörganisms on amino acids or the simpler polypeptides, it may be stated that the chemical changes involved depend largely upon the character of the organism, the conditions of growth, especially with regard to the presence or absence of oxygen, and the available source of nutrient other than amino acids.

While it is impossible to draw a distinct line of demarcation between the action of the putrefactive bacteria and of the aerobic bacteria and molds in the decomposition of amino acids, still, certain processes seem to belong to each.

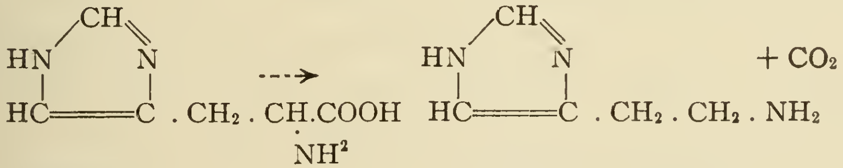
There are two general processes of decomposition of amino acids by the putrefactive bacteria. The first is the formation of amines according to the following general formulas:

$$(1)\quad R.CHNH_2.COOH \longrightarrow R.CH_2.NH_2 + CO_2$$

$$(2)\quad R.CHNH_2.COOH + H_2 \longrightarrow R.CH_2.NH_2 + H.COOH$$

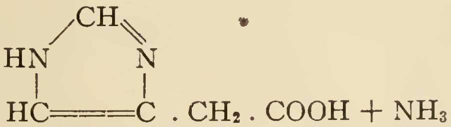
Most of the amino acids seem to yield amines on putrefaction, the formation of these following partly the first and partly the second reaction. Amine formation is prevented in the case of the monoaminodicarboxylic acids, since in this case the β- or γ-amino acid is formed: γ-aminobutyric acid from glutamic acid (Ackermann, 1910). The diamino acids especially favor this reaction, since, as Ellinger (1898–1900, i, ii) has shown, lysine and arginine yield Brieger's diamine bases, cadaverine and putrescine, respectively.

Ackermann (1910) has further shown that histidine is changed by the action of bacteria into β-imidazolethylamine according to the schematic representation:



(Histidine) (β-Imidazolethylamine)

The same investigator finds that under the same conditions some β-imidazolpropionic acid is formed from the histidine.



On the other hand it has been observed by Ehrlich and Pistschimuka (1912) that wild yeasts are able to freely change amines into alcohols with the formation of ammonia. Reaction (3):

$$(3)\quad R.CH_2.NH_2 + H_2O \longrightarrow R.CH_2OH + NH_3$$

The second general putrefactive process consists in the formation of fatty acids by the splitting off of ammonia and the concurrent entrance of hydrogen, a process of reductive desaminization:

$$(4)\quad R\,.\,CH\,NH_2\,.\,COOH + H_2 \longrightarrow R\,.\,CH_2\,.\,COOH + NH_3$$

This process is illustrated by the formation of succinic acid from aspartic acid (Hoppe-Seyler, 1877); Neuberg and Capezzuoli (1909), and of oxyphenylacetic acid from tyrosine (Baumann, 1879–1880).

Almost all of the amino acids, if not all, are capable of change by this process. Sometimes two different sorts of decomposition take place simultaneously, with the resulting formation of a hydrocarbon. In this way Kerry (1889) attempted the explanation of the formation of methane from glycocoll.

$$\underset{\text{(glycocoll)}}{CH_2\,NH_2\,.\,COOH} + H_2 \longrightarrow CH_4 + NH_3 + CO_2$$

Aerobic bacteria more frequently oxidize the α-amino acids to fatty acids containing one less carbon atom, carbon dioxide and ammonia being set free:

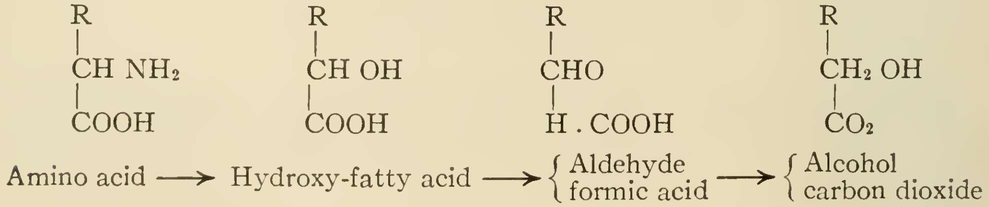
$$(5)\quad R\,.\,CH_2\,.\,CH\,NH_2\,.\,COOH + O_2 \longrightarrow R\,.\,CH_2\,.\,COOH + NH_3 + CO_2$$

In this way is formed phenylacetic acid from phenylalanine (Baumann, 1883) and isovalerianic acid from leucine (Bopp, 1846).

Ehrlich has discovered that yeasts convert amino acids into alcohols, carbon dioxide and ammonia being formed; the net result of this reaction indicates neither oxidation nor reduction but simple hydrolysis:

$$(6)\quad R\,.\,CH_2\,.\,CH\,NH_2\,.\,COOH + H_2O \longrightarrow R\,.\,CH_2\,.\,CH_2OH + NH_3 + CO_2$$

This reaction proceeds in several stages, according to Ehrlich as follows:



$$\begin{array}{l} R \\ | \\ CH\,NH_2 \\ | \\ COOH \end{array} \qquad \begin{array}{l} R \\ | \\ CH\,OH \\ | \\ COOH \end{array} \qquad \begin{array}{l} R \\ | \\ CHO \\ | \\ H\,.\,COOH \end{array} \qquad \begin{array}{l} R \\ | \\ CH_2\,OH \\ | \\ CO_2 \end{array}$$

$$\text{Amino acid} \longrightarrow \text{Hydroxy-fatty acid} \longrightarrow \left\{\begin{array}{l}\text{Aldehyde}\\ \text{formic acid}\end{array}\right. \longrightarrow \left\{\begin{array}{l}\text{Alcohol}\\ \text{carbon dioxide}\end{array}\right.$$

Neubauer and Fromherz (1911) explain the decomposition of phenylamino acetic acid to benzylalcohol by the following series of reactions:

$$\text{(A)}\quad \underset{\text{(amino acid)}}{R.CH\,NH_2.COOH} + O \longrightarrow \underset{\text{(hydrate of imino acid)}}{R.C(OH)\,NH_2.COOH} \quad \text{(Oxidation)}$$

$$\text{(B)}\quad \underset{\text{(hydrate of imino acid)}}{R.C(OH)\,NH_2.COOH} \longrightarrow \underset{\text{(keto acid)}}{R.CO.COOH} \quad \text{(Desaminization)}$$

$$\text{(C)}\quad \underset{\text{(keto acid)}}{R.CO.COOH} \longrightarrow \underset{\text{(aldehyde)}}{R.CHO + CO_2} \quad \text{(}CO_2\text{ splitting)}$$

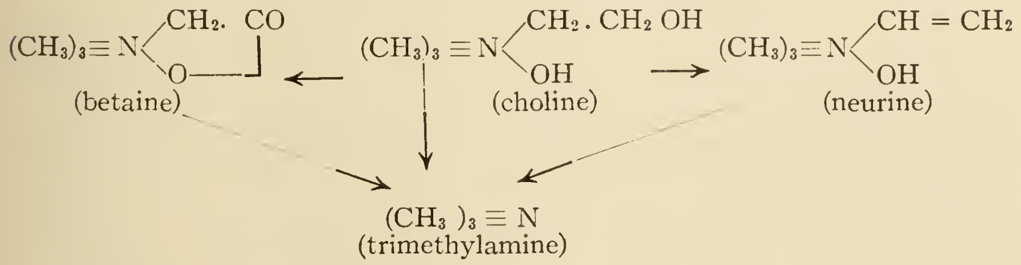
$$\text{(D)}\quad R.CHO + H_2 \longrightarrow R.CH_2\,OH. \quad \text{(Reduction)}$$

A combination of a number of these reactions may be brought about by a single organism, and different results may often be obtained using the same organism under varying conditions.

In addition to these reactions, as has already been mentioned, arginine may be split into ornithine and urea by the enzyme arginase. There exist in the soil many organisms which are capable of decomposing urea with the formation of ammonia.

Ruata and Caneva (1901) found that lecithin, a phosphoglyceride found in conjugated proteins in many cells, may be split by bacteria into choline, glycerolphosphoric acid and fatty acids. Hasenbrock (1888) and also Ackermann and Schütz (1911) have shown in turn that choline decomposes during putrefaction into ammonia, trimethylamine, carbon dioxide and methane. It is interesting in this connection to note that both choline and trimethylamine have been found in soils.

Trimethylamine is also a decomposition product of betaine, which is found widely distributed in plants. Another substance found in putrefaction, closely related to choline, which yields trimethylamine on decomposition is neurine. The relationship between these compounds may be best represented by presenting their structural formulas:



Another methylated compound which has been found in plants and animals and in the soil is creatinine. This compound contains the guanidine nucleus, which is also present in arginine. Reisser claims that creatinine is formed in the organs from either choline or betaine and urea. Twort and Mellanby (1912) have shown that numerous bacteria are able to decompose creatinine, ammonia being one of the products.

Guanidine, which has not as yet been found in soils, has been shown to be a constituent of molds and may arise by the decomposition of arginine. This compound, which is very toxic to wheat seedlings, has been found by Ulpiani and Cingolani (1905) to be a decomposition product of bacterial action on guanine, together with urea and carbon dioxide. Bierema (1909) has further shown that by the action of bacteria guanidine yields ammonia.

The fact has already been mentioned that the purines are acted upon by enzymes of a desaminizing and oxidizing character so that ammonia is formed. Uric acid, which also belongs to this class of compounds, has been extensively studied in this connection and it has been found to be readily ammonified.

The reactions cited above are some of the most important ones taking place in the soil connected with the phenomenon called ammonification. The above exposition shows that the process of ammonification from the biochemical viewpoint is extremely complex, and that it is most intimately connected with the process of the decomposition of the protein materials in the soil. However, since the process is susceptible of so many variations, the course of the decomposition cannot be foretold by the simple observation of the amount and rate of ammonia formation. It is also evident that from the same materials under certain conditions of bacterial activity one type of organic compound will be formed, while under other sets of conditions other compounds will result.

SYNTHETIC PROCESSES IN THE SOIL.

While destructive processes are taking place in the soil at all times, synthetic processes are going on as well. To the synthetic processes belong those brought about by the agency of the microorganisms and other living matter in the soil, excluding the higher plants. While these organisms decompose the nitrogenous materials in the soil, they, in order to sustain life and growth, build up protoplasm. The protoplasm of microörganisms has been found to consist to a greater or less extent of proteins, depending somewhat upon the nature of the media upon which the microörganisms have grown. Substances resembling proteins have been isolated from the bodies of bacteria, molds, and yeasts, but these have not been prepared in very pure condition. There is also evidence to show that a fairly large proportion of nucleic acid is present in microörganismal protoplasm; indeed several nucleic acids have been isolated from this class of material and the constitution of these has been pretty clearly defined. By hydrolysis of the bodies of bacteria and molds a number of amino acids have been isolated, but aside from this not much is known concerning the chemical composition and structure of the proteins contained therein. The mycelium of molds is said to be rich in lecithin, in addition to proteins and nucleic acids.

In regard to the nitrogen compounds which are present in the protoplasm of soil organisms, Omelianski and Sieber (1913) report that the bodies of Azotobacter chroococcum contain about 13 per cent. of nitrogen, which by analysis, according to the Van Slyke method, they found to be distributed as follows:

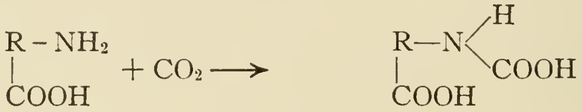
Amide nitrogen 9.6, melanin nitrogen 3.5, arginine nitrogen 10.13, histidine nitrogen 1.64, lysine nitrogen 14.60, monoamino acid nitrogen 55.40, and non-amino nitrogen 4.86 per cent., respectively, of the total hydrolysable nitrogen. The composition of other organisms would differ, since it is well known that the proteins of many organisms are specific. It would appear, furthermore, that the protein thus synthesized by microörganisms is rather resistant to the agencies of decay in the soil. This is shown, for example, by the experiment concerned with the decomposition of dried blood in soils. It has been suggested by other investigators that the bodies of bacteria might possibly be resistant to decay in the soil, particularly to nitrification, due in part to the presence in them of considerable amounts of nucleoproteins and in part to the presence of "antienzymes," which would inhibit decomposition.

That other synthetic processes go on in the soil there can be no doubt, but their presence up to this time has not been proved. It may be well, however, to consider a few of those processes of synthesis not related to vital action which probably take place in the soil.

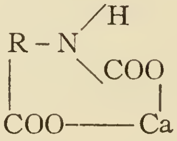
It is well known that there exist in the soil compounds which are related to the melanins, a class of poorly defined organic compounds. They are deeply colored, are generally high in carbon content and low in hydrogen, and sometimes low in nitrogen. They are generally insoluble in acids and the usual organic solvents, many of them are soluble in alkalies and are precipitated as black or brown amorphous masses from alkaline solution on the addition of acids. To this class belong the compounds produced synthetically by Maillard (1913) by the interaction of amino acids and pentose or hexose sugars. As a contribution to the chemistry of these compounds may be mentioned the work of Gortner and Blish (1915), Gortner (1916), and Roxas (1916) who show that the humin or melanin nitrogen formed on the hydrolysis of certain proteins by mineral acids is chiefly due to the interaction of tryptophane and glucose, while tyrosine, cystine, arginine, lysine and histidine also contribute, but to a very minor degree.

It has been suggested that the nitrogen in such compounds exists in complex ring combinations and under such conditions is probably not easily subject to change in the soil.

Another type of chemical synthesis which may possibly take place in the soil is that which results in the formation of carbamino acids. Siegfried showed in 1905 that when carbon dioxide is passed into a solution of the calcium or barium salts of the monoamino acids that the corresponding salts of the carbamino acids were formed according to the following general reaction:



The calcium salt of this dibasic acid has the following structure:



This type of compound may also be formed in the same manner from the monoamino dibasic acids, the diamino acids, polypeptides, peptones and proteins. The calcium salts of some of these compounds are rather insoluble in water. We know that there are present in the soil the conditions necessary for the formation of such compounds since carbon dioxide is liberated in large quantities during the decay of organic matter and, if not already present, lime is commonly added to soil to correct acidity.

From these examples an idea of the complexity of the compounds built up in the soil by purely chemical reactions is obtained. These synthetic processes are just beginning to be studied and may be of deep significance to soil fertility.

THE CHEMICAL METHODS OF EXAMINATION.

The chemical methods used in this investigation may be divided into two classes, (1) analytical and (2) isolation methods. It is not the purpose of the present paper to dwell at any length on the methods used, but for a clear understanding of the mode of attack and the problem at hand these will be described in principle. For the special details involved, particularly in the isolation and identification methods, the reader is referred to the original papers dealing with the isolation of these compounds from soils and from other material.

ANALYTICAL METHODS.

Total nitrogen was determined by the Kjeldahl-Gunning-Arnold method (Trescot, 1913).

Ammonia was determined by distilling in vacuum a mixture of the substance with a 10 per cent. solution of calcium hydroxide into N/10 sulfuric acid and titrating with N/20 sodium hydroxide, using alizarine red as an indicator.

Nitrogen Partition.—For the purpose of determining the forms of nitrogen resulting from hydrolysis of the protein materials the method described by Van Slyke (1911, 1912) was used. This method, which is based on the fact that amino groupings will react to form free nitrogen according to the formula:

$$R\,.\,CH\,NH_2\,.\,COOH + HNO_2 = R\,.\,CH\,OH\,.\,COOH + N_2 + H_2O,$$

has proved to be extremely useful in biochemical work. Van Slyke (1915) states in a recent article that the method was designed only for use with pure proteins not accompanied by other classes of substances, particularly nitrogenous compounds. The presence of these would obviously render the interpretation of the results faulty unless the behavior of the nonprotein substances were so clearly understood that corrections might be made. It must be clear that during the decay in the soil of such complex protein materials undoubtedly compounds other than proteins or the primary decomposition products of these must make their appearance. Just what these compounds may be we can but conjecture at this time, so that the results of the Van Slyke method when applied to the partition of the forms of nitrogen in the soil, while reported as lysine nitrogen, arginine nitrogen, etc., can only be considered approximations for the amounts of these various forms actually present in the soil in proteins or as primary decomposition products of proteins. It should be emphasized, however, that such a method is of decided value, even under such limiting circumstances, in attacking problems like those at hand, since by the use of such a method it is possible to divide the nitrogenous compounds present in the soil or fertilizer into a number of classes which react towards the various reagents involved in the analytical procedure as though they were arginine, histidine, etc. The very fact that a given nitrogenous compound will, towards a given chemical reagent, or a series of them, react like arginine, histidine, etc., establishes a chemical, and possibly a biochemical, relationship.

By the use of the Van Slyke method the nitrogen is divided into the following fractions: Amide nitrogen, melanin nitrogen, arginine nitrogen, histidine nitrogen, lysine nitrogen, mono-amino acid nitrogen and non-amino nitrogen.

Moisture determinations were made by drying the soil samples in an electrically heated air bath for 2 hours at 103° C. All analyses are reported on an oven-dried basis.

METHODS OF ISOLATION AND IDENTIFICATION.

The methods which have been selected for the isolation and identification of the compounds discussed in this paper were originally designed for the isolation of these from plants, flesh, etc., where the interfering factors are not so great. When these methods are applied to soils, where both the mineral and organic matter are very complex, the interfering compounds are numerous and occur in such quantities at times that the compounds sought for are completely obscured. The various fractions finally obtained for the isolation of the nitrogenous compounds are always contaminated with coloring matter, resinous material, and other compounds, in part precipitated by the metallic salts used or in part dissolved by the same solvents. Such foreign material must be eliminated by careful precipitation and repeated solution. This purification, which is sometimes almost impossible on account of the nature and quantity of the contaminating materials, often yields only extremely minute quantities of the pure compound. Moreover, the isolation methods must be varied for each and every soil, since the nature of the organic matter of each soil is not only different but the organic compounds are present in different proportions and combinations. Frequently a compound can be isolated by more than one procedure, but this can only be ascertained by experimentation.

Experience has shown that samples of at least 100 pounds of soil should be available for the isolation of organic compounds. The soil, in lots of about 40 pounds, was stirred for several hours with about 20 gallons of 1 to 2 per cent. sodium hydroxide solution in a large porcelain-lined kettle provided with a power stirring device. The stirrer was then removed, the soil allowed to settle, usually over night, and the solution was drawn off by means of a siphon. To the soil solution so obtained a suitable acid, depending on the ensuing procedure, was added until the silt and humus bodies were well flocculated. Providing the methods to be used would not be interfered with by large amounts of iron salts, the acid solution was then filtered through a filter press under pressure. If, however, iron salts would be objectionable, the solution was filtered through filter paper in the usual way. In either case after the filtered solution had been made exactly neutral with sodium hydroxide it was concentrated to a volume of 2 to 3 gallons in a vacuum pan, the temperature of the liquid not rising above 52° C. In this way large quantities of soil were easily and safely handled and a great deal of time saved.

The action of the weak alkaline solution is apparently to remove the resinous and similar material from the soil grains and to dissolve water-soluble material, as well as to form sodium salts with any of the acids which are present in the soil.

The acid filtrate, after neutralization, was used for the isolation of the nitrogenous compounds.

The Purine Bases and Creatinine.—The original soil extract was made acid with sulfuric acid, and after filtering and concentrating was made quite alkaline with sodium hydroxide and the precipitate, consisting largely of the hydroxides of iron and aluminum, filtered from the solution. The bases were then precipitated by boiling with Fehling's solution and a little dextrose. The copper precipitate, after thorough washing with sodium acetate solution and then with alcohol, was suspended in water and decomposed with hydrogen sulfide, and after the sulfides were removed by boiling and filtering, the solution was concentrated to about 150 c.c. Small portions of this solution were tested for the presence of the purine bases and for creatinine by the following color reactions: (1) The Xanthine reaction, which is given by xanthine and guanine, (2) Weidel's reaction, which is given by xanthine and guanine, (3) Kossel's test, which is given by xanthine, hypoxanthine, guanine and adenine, (4) Jaffe's reaction, (5) Weyl's reaction and (6) Salkowski's test, all three of which are given by creatinine.

If the three color reactions were positive for *creatinine* in the solution tested, zinc chloride and sodium acetate were added to a portion of the solution and allowed to stand for several days, when the characteristic crystals of creatinine zinc chloride were formed. These were collected on a porous plate, washed with a little cold water, boiled with a little freshly precipitated lead hydroxide, filtered, and the filtrate concentrated to a small volume; on standing for several hours crystals having the characteristic form, solubility and color reactions of creatinine were obtained.

The remaining portion of the solution containing the purine bases was made ammoniacal and the bases precipitated with ammoniacal silver nitrate. The precipitate was filtered off, washed well with cold water, boiled with nitric acid (sp. gr. 1.10), and the solution filtered hot. On standing, if hypoxanthine, adenine or guanine were present, they separated out in the form of their silver nitrate salts, while the xanthine remained in solution. The crystals were filtered off, decomposed in boiling water with hydrogen sulfide and after the sulfides were removed ammonia was added to the solution, when *guanine,* if present, separated out and was filtered off. The precipitate was washed with a little cold water and was then dissolved in a little warm dilute hydrochloric acid. The guanine was then identified by means of its color reactions, and its characteristic salts, of which the picrate, described by Capranica, and the dichromate described by Wulff, are perhaps the best.

The filtrate from the guanine, which contained both hypoxanthine and adenine, was treated with picric acid, when the *adenine,* if present, was precipitated as adenine picrate. This was filtered off, washed with a little cold water, taken up in a solution of a little dilute hydrochloric acid, the solution shaken out with ether, made alkaline with sodium hydroxide, and the adenine precipitated as the copper salt, with Fehling's solution and dextrose. After treatment of this precipitate with hydrogen sulfide the adenine was further identified by the formation of its various characteristic salts—the hydrochloride, the nitrate, the dichromate, the picrate, and the platinum chloride.

The filtrate from the adenine picrate was treated with dilute sulfuric acid, extracted with benzol to remove the picric acid, and then precipitated in ammoniacal solution with ammoniacal silver nitrate solution. This precipitate, after washing, was decomposed with hydrogen sulfide, and after being freed from sulfides and after evaporation the *hypoxanthine* was identified by the formation of the hydrochloride, the nitrate, the platinum chloride, and the silver picrate salts.

The *xanthine* portion from the nitric acid treatment was made alkaline with ammonia, and the resulting precipitate, after washing, was decomposed with hydrogen sulfide and the xanthine identified by color reactions, and by the hydrochloride, the nitrate, and by the crystalline form of the base itself.

Cytosine.—For the isolation of this compound sulfuric acid was also used to acidify the alkaline extract from the soil. The concentrated neutral solution obtained from the vacuum pan was filtered, made acid with sulfuric acid, an excess of mercuric sulfate solution was added, and the whole allowed to stand for 24 hours. The precipitate which formed was filtered off, washed well, and after being suspended in water was decomposed with hydrogen sulfide. When the sulfides had been removed the solution was evaporated to a small volume and allowed to stand for a time. A crystalline mass separated out, which was mixed with coloring matter and foreign material; consequently the solution was evaporated to dryness and extracted a number of times with absolute alcohol. The alcohol removed much of the coloring matter, and by repeated fractional crystallization from water a white compound was obtained which showed the characteristic crystalline structure and shiny appearance of cytosine. This compound was further identified by its solubility in water, alcohol, and ether, and the preparation of the platinum chloride, hydrochloride, picrate, and potassium-bismuth iodide salts.

Nucleic Acid.—In this case acetic acid was used to acidify the alkaline soil extract, and the concentrated liquor was filtered hot. After cooling, a little more than an equal volume of 95 per cent. alcohol was added to the solution and enough hydrochloric acid to make the solution acid to about 5 per cent. After standing several days the precipitate was filtered off, washed with water, and dissolved in dilute sodium hydroxide solution. The nucleic acid was again precipitated by the addition of sodium acetate, hydrochloric acid and alcohol. The precipitate was filtered, washed and dissolved in dilute ammonium hydroxide. To this solution lead acetate was added to complete precipitation, and the precipitate was filtered off and washed thoroughly with water. The precipitate was broken up, after suspension in a large volume of water, with sulfuric acid, care being taken to avoid any excess of acid. From this solution the nucleic acid was again precipitated as before and the precipitate after thorough washing on the filter was dried. The compound so obtained was fairly light in color and was amorphous. A portion of it was boiled with concentrated hydrochloric acid and tested for pentoses with the phloroglucin and orcin tests, which showed their presence. Another portion was evaporated with magnesium nitrate, ignited, and the residue taken up with hydrochloric acid. The solution gave tests for phosphates, both with ammonium molybdate solution and with magnesia mixture. The remainder of the substance was boiled with hydrochloric acid, made alkaline with sodium hydroxide and the purine bases precipitated with Fehling's solution and dextrose. From this point the procedure was identical with that described under the isolation of the purine bases. The bases, however, were usually obtained in such small quantities that their individual identity could not be ascertained.

Diamino Acids.—The alkaline extract of the soil was made just acid with sulfuric acid and filtered. After concentration, the solution was made acid to about 5 per cent. and filtered hot. After cooling, phosphotungstic acid was added until precipitation ceased, when the solution and the precipitate were allowed to stand for several days. The precipitate was then filtered off and washed with dilute sulfuric acid solution which contained a little phosphotungstic acid. The precipitate was carefully dissolved in 45 per cent. sodium hydroxide solution, using phenolphthalein as an indicator and adding at no time more than two drops of the alkaline solution. Water was then added until a volume of about 1000 c.c. was reached and barium hydroxide solution was added until the phosphotungstate acid was precipitated. After filtering off the barium phosphotungstate and barium sulfate, the solution was just neutralized with sulfuric acid and was then evaporated almost to dryness with barium carbonate in order to expel all of the ammonia. The residue was taken up in about 1000 c.c. of hot water and filtered, and the precipitate washed with hot water. The filtrate was placed in a large flask and treated while hot with solid silver sulfate, which was added slowly until the solution contained sufficient to give a yellow precipitate when a drop was removed and tested with a saturated solution of barium hydroxide. The solution was then filtered and the separation of the three hexone bases was carried out according to the method of Kossel and Kutscher (1900), by means of precipitation with baryta.

Lysine was identified by means of its manner of isolation, the formation of its picrate, hydrochloride, and platinum chloride salts and by the action of the base itself.

Histidine was identified by its manner of isolation, the formation of the characteristic dichloride salt, the formation of the picrolonate, and its color reaction.

Arginine was identified by the manner in which it was obtained, and by the formation of the acid and neutral nitrate salts, the formation of the copper nitrate salt, the picrolonate, and by the properties of the free base itself.

Monoamino Acids.—The filtrate from the phosphotungstic acid precipitate above was made alkaline with barium hydroxide in order to remove the sulfuric and phosphotungstic acids, and filtered. The filtrate was concentrated and nearly neutralized with sulfuric acid. This slightly alkaline solution, about 500 c.c. in volume, was treated by boiling with freshly precipitated copper hydroxide, and was then poured into about 3000 c.c. of 95 per cent. alcohol and allowed to stand over night in order that the insoluble mineral matter might settle out. The deep-blue alcoholic solution was then filtered, the insoluble salts dissolved in water, and reprecipitated by pouring into alcohol as before. The alcoholic solutions were then combined and evaporated to dryness, the residue was taken up in hot water and the copper removed by treatment with hydrogen sulfide. After filtering from the copper sulfide, the solution, which contained considerable color, was boiled with animal charcoal. The filtered solution was made faintly alkaline with ammonia and treated with freshly prepared copper hydroxide, keeping the volume of the solution at about 1000 c.c. The solution was filtered from the excess of copper hydroxide and evaporated to dryness on the steam bath. The solid residue was then scraped from the sides of the dish and extracted in a Soxhlet extractor with absolute methyl alcohol until no further blue color was imparted to the alcohol.

Leucine.—The alcohol insoluble portion was dissolved in a large volume of boiling water and the copper removed with hydrogen sulfide. The solution was filtered, boiled down to a volume of about 50 c.c. and treated with ammoniacal lead acetate until no further precipitation took place. The precipitate was washed with 95 per cent. alcohol and was finally decomposed with hydrogen sulfide, after suspending in water. On concentration of a portion of this solution, the characteristic crystals of impure leucine formed. The crystals were redissolved in water and added to the original solution, which was boiled with animal charcoal until the color was removed from the solution. The leucine was then purified as before by the formation of the copper salt and the basic lead salt. On concentrating the solution obtained from this purification crystals of pure leucine were obtained. They were identified by their crystalline form, solubility, the fact that the leucine sublimed, the crystalline form and solubility of the copper salt, and by the color reactions with quinone.

Tyrosine.—The methyl alcohol solution of the copper salts was evaporated to dryness, and the residue taken up in water. The copper was removed with hydrogen sulfide and the solution boiled with animal charcoal. After filtering the solution was concentrated and the long silky needles of tyrosine began to separate out. The needles were filtered off and extracted with boiling 70 per cent. alcohol. The crystalline residue was recrystallized from water several times and dried on a porous plate. Tyrosine was identified by its crystalline structure, its solubility in water, alcohol, acetic acid, ammonia, by the preparation of the copper salt, and by the color reaction given with Millon's reagent, and the color reaction of ferric chloride with the sulfonic acid prepared from tyrosine.

THE DISTRIBUTION OF PROTEIN DECOMPOSITION PRODUCTS IN SOILS.

In order to attain an adequate concept of the processes taking place in the soil and of the interrelations of the compounds occurring in soils it is not only necessary to isolate compounds from one soil but it becomes of importance also to study the distribution of such compounds in many soils. By such knowledge only does it become possible to formulate a rational theory as to the nature of the organic matter normally found in soils. It is advisable to know whether a compound is a constituent peculiar to the soil from which it was isolated or whether it is of general occurrence in soils. Does it appear in one and the same soil under all conditions, or is it the result of special treatments or farm practices? It is obviously of the greatest importance to know under what soil conditions and in what soils or class of soils any particular compound or group of compounds exists in order that a true and comprehensive view of organic matter in soils be obtained. In a word, it is necessary for the investigator interested in developing the science of agriculture from the standpoint of the relations of the biochemical and biological processes in the soil to the problem of soil fertility to be able to distinguish between what is normal to soils and what is abnormal. Therefore, a survey of the nitrogenous decomposition products of protein material occurring in a large number of soils from widely different regions was made.

THE SOILS STUDIED.

The results obtained on a number of samples of soil from different localities by the application of the methods of isolation and identification, which have already been described, are briefly given in the following paragraphs, the soils being grouped by States in which the samples were collected.

Maine.—Two samples of Orono clay from the vicinity of Oldtown, Me. In both samples histidine was found, and in one of the samples there was found, in addition, hypoxanthine.

Massachusetts.—Five samples from various parts of the Boston Common, Boston, Mass. All of these samples showed the presence of cytosine and hypoxanthine. These samples all represent different sorts of soil.

New York.—A sample of Volusia silt loam from Ontario, N. Y., showed the presence in the surface soil of cytosine, histidine, choline,[1] creatinine,[2] nucleic acid,[2] and in the subsoil hypoxanthine was found in addition to cytosine and histidine.

A sample of Clyde loam from Orleans County, N. Y., contained in the surface soil histidine, cytosine and hypoxanthine. The sample of subsoil showed in addition to these compounds the presence of xanthine.

The examination of a muck soil from Orleans County, N. Y., showed in the upper as well as in the lower layers the presence of histidine.

A sample of Dunkirk clay contained creatinine.[2]

Pennsylvania.—A sample of Chester silt loam from near Philadelphia, Pa., showed the presence of cytosine, arginine, xanthine and hypoxanthine.

A sample of Frankstown stony loam from Bedford County, Pa., contained histidine and creatinine[3] in the surface soil and histidine in the subsoil.

Maryland.—A sample of Elkton silt loam from near Easton, Md., contained nucleic acid, xanthine, adenine, histidine, and creatinine.

A sample of Sassafras silt loam from the same field contained nucleic acid, hypoxanthine, histidine, and creatinine.

West Virginia.—Samples of both surface and subsoil of Dekalb silt loam from the vicinity of Ravenswood, W. Va., showed the presence of histidine.

Kentucky.—A sample of Clarksville silt loam from near Broadhead, Ky., showed the presence of histidine and creatinine.[3]

Mississippi.—Investigations on a sample of Houston clay from Nuxobee County, Miss., showed the presence of histidine[4] and arginine.[4]

Texas.—A sample of Amarillo silt loam from Sherman County, Texas, showed the presence of histidine in both surface soil and subsoil.

North Dakota.—A sample of Marshall clay from Fargo, N. D., showed the presence of arginine,[3] histidine,[3] and cytosine.[3]

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[1] Shorey, 1913.

[2] Shorey, 1912, i, ii.

[3] Shorey, 1912, i.

[4] Schreiner and Shorey, 1910.

California.—From a sample taken from an orange grove near Riverside, Calif., lysine [1] and nucleic [1] acid were isolated.

Georgia.—From a salt marsh near Brunswick, Ga., trimethylamine [1] was isolated.

Connecticut.—From a soil from near Redding, Conn., adenine [1] was isolated.

The occurrence of these decomposition products of proteins and nucleoproteins in many soils may be summarized as follows:

Histidine, arginine and lysine, the three hexone bases, are primary decomposition products of proteins. Histidine was found in eighteen of the twenty-four soils examined for its presence; arginine was found in but two soils and lysine in but one. This indicates that histidine is a fairly common constituent of soils, and shows, therefore, that the protein cleavage in the soil is of the same nature as that brought about in the laboratory. It further shows that histidine is quite resistant to bacterial decomposition. Arginine and lysine which are also present in almost all proteins seem to be not so common to soil organic matter; they are no doubt formed in the soil, but unlike histidine, their nitrogen is contained in chain linkage and not in ring formation and they are therefore more easily subject to decomposition in the soil.

Nucleic acids were isolated from four of the soils examined for them.

The three purine bases, adenine, xanthine and hypoxanthine, and the pyrimidine base, cytosine, are products of the biochemical decomposition of nucleic acids. Hypoxanthine was found in twelve of the twenty-four soils examined; cytosine was also obtained from twelve of the soils. These two bases were found associated in eight of the twelve soils. Xanthine was found in four of the twenty-four soils and was associated with hypoxanthine in three of these. Adenine was found in but two of the soils and was associated with xanthine in one of these.

Hypoxanthine and cytosine seem to be more resistant to bacterial action in soils than the other purine and pyrimidine bases, and this may explain their more frequent occurrence. Xanthine is rather easily oxidized to uric acid and this is easily decomposed in the soil. Adenine is changed by desaminization into hypoxanthine and this may explain the more frequent occurrence of hypoxanthine in soils and the infrequency of the occurrence of adenine. Cytosine and hypoxanthine seem then to be normally occurring soil constituents, being found in about half of the soils examined for their presence; xanthine occurs less frequently than these, and adenine only to a limited extent.

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[1] Schreiner and Shorey, 1910.

Creatinine has been found in six of the ten soils examined for it and seems to be a regularly occurring soil constituent, likely to occur in all soils.

Choline and trimethylamine have each been found in but one soil, but no survey has been made for the distribution of these compounds. It is quite likely, however, that their occurrence is not usual in soils.

Tetracarbonimid has been isolated from a soil from Virginia. A compound having similar properties has been obtained from several other soils in Florida and Maryland but in such small quantities that its identity could not be established as tetracarbonimid. (Shorey and Walters, 1914.) Owing to the very similar properties of cyanuric acid it is uncertain whether this compound is tetracarbonimid or cyanuric acid.

Cyanuric acid has been reported as having been isolated from five soils examined for its presence; soils from Indiana, Florida, Maine, District of Columbia, and Texas. It is uncertain in the light of our present knowledge whether cyanuric acid or its isomer cyamelid occurs as such in soil. (Wise and Walters, 1917.)

The presence of urea in forest soils, truck soils, humus soils, and virgin soils of France has been reported by Fosse (1916).

(*To be continued.*)

THE EQUIVALENT MASS IN RIGID DYNAMICS, WITH APPLICATIONS TO GYROSCOPES AND SCREW PROPELLERS.*

BY

A. F. ZAHM, M.E., Ph.D.,

WITH DIAGRAM AND DATA BY

W. P. LOO, M.S.

PREFACE.

In the analysis of the motion of a rigid body, the forces acting upon it may be replaced by three component forces acting along the principal axes through its centroid, and three component couples acting about those axes. Then the translation of the centroid is determined from the mass and three component forces; the rotation about the centroid is determined from the principal moments of inertia and the component couples. From the original given forces, therefore, the entire motion of the body can be found if its mass and principal moments of inertia be known, even though the shape and distribution of mass be disregarded or unknown.

THEORY OF EQUIVALENT MASS.

In analyzing the motion of any given rigid body, it is always possible, and sometimes more convenient, to employ in place of the actual body a kinetic equivalent, that is, a mass distribution which would, under the given system of forces, have the same translation and rotation as the actual body. For example, suppose the given body to be specified by mass M and principal moments of inertia A, B, C, and choose for equivalent body the point-mass distribution shown in Fig. 1, and defined by the following equations in which a, b, c, are distances from the origin of the equal point-masses M/6.

$$\left.\begin{aligned} b^2+c^2&=3\ \mathrm{A/M} \\ a^2+c^2&=3\ \mathrm{B/M} \\ a^2+b^2&=3\ \mathrm{C/M} \end{aligned}\right\} \text{-------}\ (1)$$

Then, since the right members are given, the massless arms a, b, c, and hence the required space distributions, are fully determined, providing the arms be real.

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* Communicated by the author, September, 1916.

To show that a, b, c, are always real, note from equation (1) that $a^2 = \frac{3}{2M}(C-A+B)$, so that a cannot be imaginary unless A be greater than C + B. Now, if m be any particle at x, y, z, of any rigid body,

$$\left.\begin{aligned} A &= \Sigma\, m\,(y^2+z^2) \\ B &= \Sigma\, m\,(x^2+z^2) \\ C &= \Sigma\, m\,(x^3+y^2) \end{aligned}\right\} \text{- - - - - - - (2)}$$

Hence, $a^2 = \frac{3}{2M}(C-A+B) = \frac{3}{M}\Sigma\, mx^2$, which is always positive, *i.e.*, a is always real. Similarly b and c are always real. Writing $\Sigma\, mx^2 = Mx_1^2$ gives $a = \pm\sqrt{3}x_1$; similarly $b = \pm\sqrt{3}x_1$ $c = \pm\sqrt{3}z_1$, where x_1, y_1, x_1 are the radii of inertia referred to the principal planes.

In the most general case of rotation about three axes, each particle of the six-point equivalent mass exerts a gyroscopic torque whose magnitude and direction may be found by the method employed for a single gyroscopic particle. The component torques so found can be compounded in the usual way to obtain the resultant torque.

A six-point equivalent mass has been used here as a convenience; other distributions comprising fewer or more particles may obviously be employed.

Examples.—As illustration, suppose the model to represent a gyroscope rotating steadily about two axes only, say X and Z, its centroid being either stationary or in motion. Then the masses at a, a, taken together obviously exert no resultant moment, for they have no gyroscopic acceleration, and any acceleration they may have from their translatory motion is, in magnitude and direction, the same for both. From this it follows that such a rigid body has the same gyroscopic torque whether its mass be all in the plane of rotation Y Z, or not; that is, whether a be zero or of any finite magnitude. Hence the gyroscopic torques about Y and Z, of any rigid solid rotating about X and Z may be derived from the treatment of a point mass distribution in the Y Z plane, say four equal particles spaced as shown in Fig. 1, at b, b, c, c.

It has been proved elsewhere [1] that a single particle of a gyroscope in steady[2] rotation and precession has about the nutation axis a torque proportional to the sine square of its angular distance from that axis. Four equal particles symmetrically placed about the rotation axis have, therefore, about the nutation axis a resultant torque which is constant and equal to twice the maximum torque of one particle. Hence any mass having kinetic symmetry about the rotation axis, since it is the gyroscopic equivalent of a four-particle mass, has a constant torque equal to twice the maximum of one such particle. This generalization can, of course, be derived algebraically from the above mentioned sine square law. For example, it can thus be shown that n equal particles or radial lines symmetrically spaced about an axis have, if n exceed 2, a constant gyroscopic torque which is n/2 times the maximum for one particle or line.

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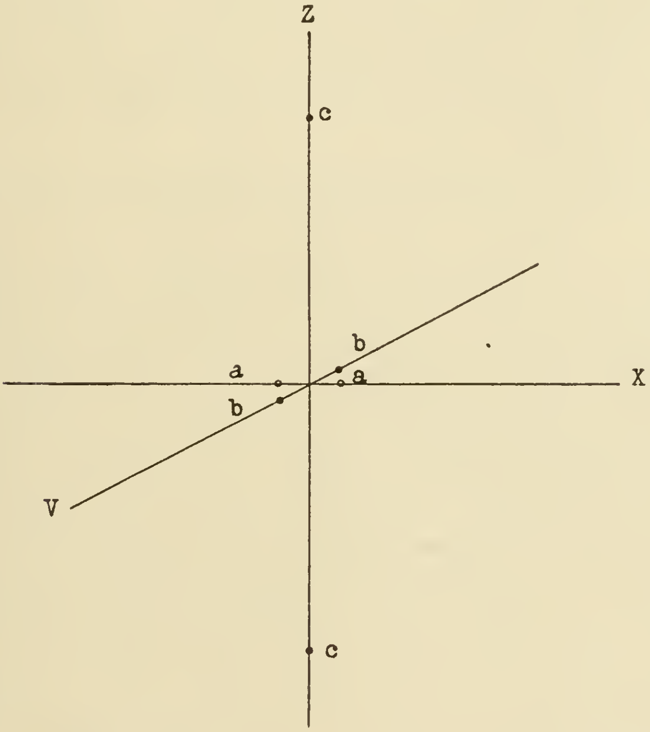
[1] *Aerial Age Weekly*, September 25, 1916.

FIG. 1



Mass-equivalent of Curtiss two-blade air screw. Diameter, 8′-6″, Mass, 42 lbs., a=3.9 in. b=4.24 in., c=34.2 in.

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[2] This restriction was merely a convenience. It is well known that the gyroscopic force and torque of any given body are the same for any specified angular velocities whether the motion be steady or accelerated.

Summary.—The foregoing treatment of the mass-equivalent of a rigid body may be summarized as follows:

Every rigid body has a mass-equivalent whose motion under given forces is the same as that of the body itself. In particular, any rigid body has as mass-equivalent six equal particles suitably placed on its principal centroidal axes and invariably connected by massless bonds.

A six-particle mass-equivalent reduces to four particles for a plane distribution; two for a rectilinear. The arms of the six particle mass-equivalent of any rigid body equal respectively its radii of inertia referred to the reference planes, multiplied by $\sqrt{3}$.

The gyroscopic torque about its centroid of any rigid body is unaffected by its linear or angular acceleration or by the linear speed of its centroid.

At any instant the gyroscopic torque of a rigid body is the resultant of the torques of its equivalent mass particles.[3]

Application.—Fig. 1 shows the equivalent mass, derived from experimental data, for a standard Curtiss two-blade propeller. From this figure we can judge the comparative gyroscopic value of the distribution of the propeller mass in each of the three axial directions, since this value varies as the square of the arm lengths, a, b, c, and as the products in pairs of the angular velocities, ω_x, ω_y, ω_z, about those arms. In fact the ratios of the three maximum gyroscopic torques of the pairs of point-masses are as $c^2 \omega_x \omega_z : b^2 \omega_x \omega_y : a^2 \omega_y \omega_z$. In practice the angular velocities may have the values 150, 0.5, 0.5 radians per second, thus making the two largest torque ratios $c^2\omega_x\omega_z/b^2\omega_x\omega_y = 65$, and $c^2\omega_x\omega_z/a^2\omega_y\omega_z = 23100$. The resultant of the three component torques is at most, therefore, only $\sqrt{1+(1/65)^2+(1/23100)^2}$ times the major one, that is, about one-eightieth of one per cent. greater. The gyroscopic value of such a propeller, so running, may therefore with great accuracy be equated to that of a pair of simple particles.

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[3] As is well known, the gyroscopic torque of any particle equals its angular momentum times its deviation or the rate of angular change of its plane of rotation.

THE PRODUCTION OF LIGHT BY ANIMALS.*

BY

ULRIC DAHLGREN,

Professor of Biology, Princeton University.

LIGHT PRODUCTION BY THE ELATERID BEETLES.

THE elaterid beetles are a group of elongate forms found all over the world and commonly known to English-speaking people as "spring-beetles," "snap-beetles," or "jumping-beetles." No less than 2700 species are known from various countries. Of the nine genera mentioned by Leunis, one, the genus Pyrophorus, has the power of lighting. Almost one hundred species of this genus are found in tropical America varying in size from a few millimetres long up to others that attain a length of over four centimetres.

The commonest and best known of these is *Pyrophorus noctilucus,* a brown-colored beetle about 3.2 centimetres long (see Fig. 1). It flies about at night emitting bright blue-green or greenish flashes and remains inert under bark or leaves in the daytime. It is used as a plaything by children or even as an ornament in the hair by ladies, and can be gathered in large numbers when the height of its breeding season is on. Its larva is a very different appearing creature, being very long and very thin in the dorso-ventral direction, of a light cream color with a dark brown head and jaws, these latter strong and used to bore its way through roots of the sugar cane in which it lives and on which it is reported to feed (see Fig. 2). Other observers report it to be a predatory form, living on other animals.

The elongated body of the adult insect shows three large and distinct light organs. Two of these show round or slightly oval spots of about 1.5 mm., symmetrically placed on each side of the upper surface of the thorax toward its posterior end. Fig. 1 shows these organs. The third is a single median organ placed on the anterior ventral surface of the abdomen and is partly covered by the thorax when the insect is at rest. In shape it is an irregular heart-shaped area in the female (see Fig. 3) and a much larger organ with wide reaching lateral wings and with its anterior edge marked by one median and two symmetrical lateral notches which partly mark it into four lobes (see Fig. 4) in the male. Over both thoracic and abdominal organs the chitinous covering of the body is of a clear and transparent yellowish color plainly showing the white color of the deep reflecting layer. On all other parts it is dark brown, so that the luminous organs stand out plainly to the eye when the animal is examined in daylight or lamplight.

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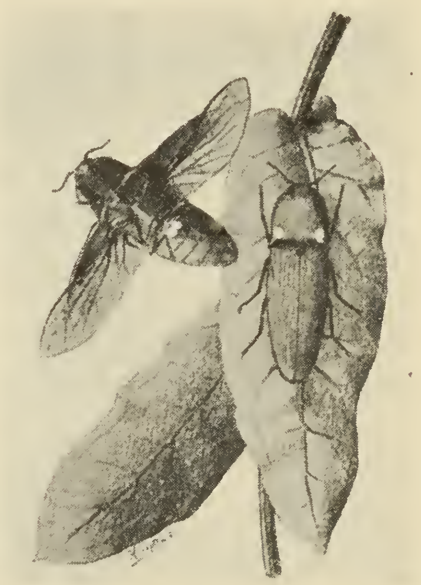
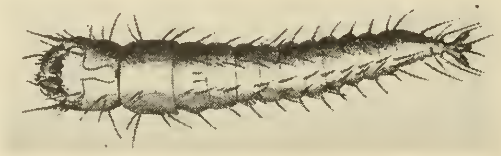
* Continued from page 94, vol. 183, January, 1917.

FIG. 1.



Drawing of the luminous beetle, *Pyrophorus noctilucus*. One flying and one resting on a twig. Shows the two thoracic light organs and the single abdominal light organ. After Mangold.

FIG. 2.



Young larva of the luminous beetle, *Pyrophorus noctilucus*. After Dubois.

The manner of illumination is interesting. Ordinarily, when at rest or even most of the time while flying, the creature shows no light at all. If a resting beetle is seized in the hand and annoyed by rubbing or pressing, a clear greenish light appears in the two thoracic organs, slowly attaining a maximum brightness and glowing until the annoyance has ceased, when it slowly dies away. During this time the abdominal organ shows no signs of light.

Only while flying in the breeding season does this larger organ come into play. Then, as the insect flies in swift lines and circles around the shrubs and palm trees, it gives repeated long flashes with its abdominal light organ. The flash is very bright and on account of its lasting quality gives the eye an impression of a streak of light rather than a single flash. This flash is said to be yellower or redder than the flash of the thoracic organs.

FIG. 3.

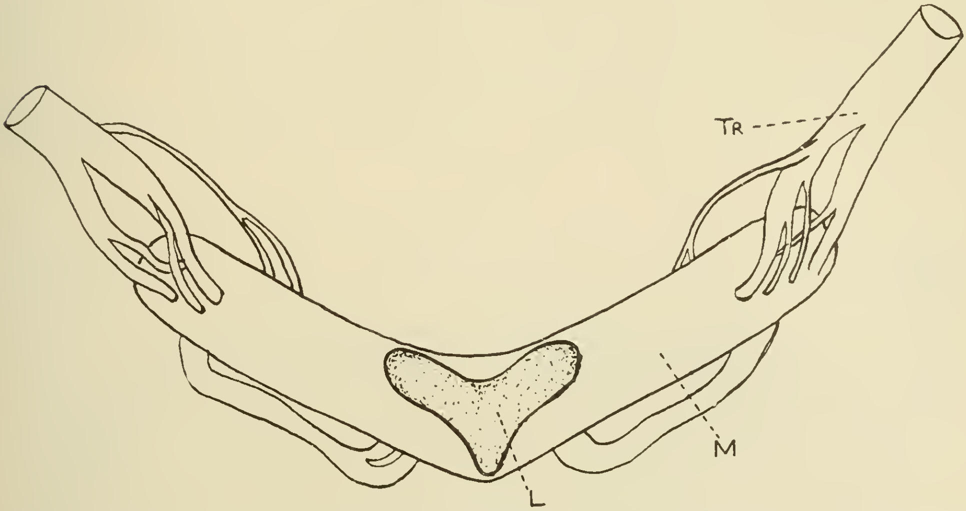


Diagram of a dissection of the abdominal light organ of the female *Pyrophorus*. *m*, muscles; *l*, light organ; *tr*, tracheæ. After Geipel.

FIG. 4.

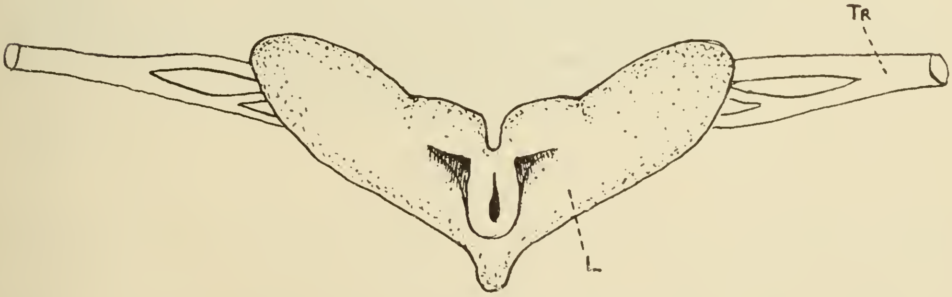


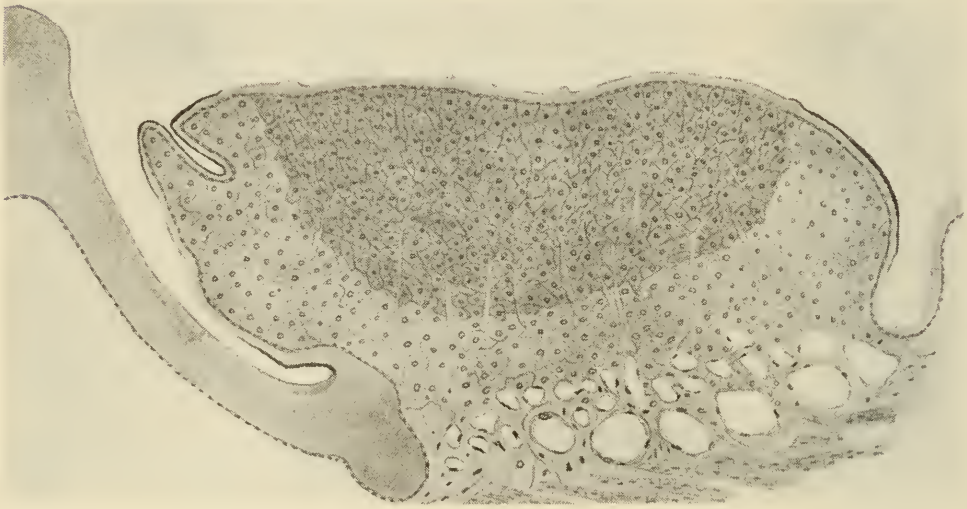
Diagram of a general dissection of the abdominal light organ of the male *Pyrophorus*. *l*, light organ; *tr*, tracheæ. After Geipel.

If the abdomen of a living specimen is cut off or torn from the thorax the organ may light, but usually does not. If the separated abdomen is gently pressed and released several times to bring about artificial breathing, the light will appear at about the fourth to seventh "breath." It can also be brought to lighting by stimulating the proper ganglion in the central nervous system with a needle, as can also the thoracic organs.

Dissection of the organs shows all of them to have essentially the same structure although they vary somewhat in morphological details. Each one consists of a thickened plate of two layers of cells lying parallel with and against the "window" of transparent chitin that marks the organ. Large tracheal stems approach the organ from each side and form by division a network of finer air channels through its substances.

Fig. 5 shows a vertical longitudinal section through the anterior portion of the abdomen and will serve to show the general relations of the organ to its surrounding tissues. It can here be noticed that the entire organ forms a mass that protrudes slightly from the body and at the same time its point of origin is somewhat sunken so that its outer surface is, after all, on about the level of the rest of the surrounding surface. As can be seen in the figure the chitinous covering of the body is a thick tough one with the color appearing in its outer third. Immediately around the organ this dips sharply downward and at the same time becomes somewhat thinner. As it turns sharply upward to ascend over the surface of the organ it attains its very thin condition over the entire organ surface. In the ascending zone, and for a

FIG. 5.



Vertical longitudinal section under low magnification of the abdominal light organ of a male *Pyrophorus*.

short distance over the surface, it is thin, but it shows a dense black pigment on its outer surface. This pigment appears in life as a black outer rim to the entire structure. Immediately over the larger central portions of the organ the chitin is, as has been said, colorless and very thin. Its thickness is modified in places by irregularities of its outer surface as shown in the figure.

The chitin, both of body and organ, is lined on its inner surface by a layer of hypodermal cells, as in all arthropods. These cells are, in the adult beetle, very thin and evidently of no important function. They were much more vigorous looking and vital in staining power at the time when, in the pupa, they were engaged in forming and building up the cuticle. If anything, they are in better condition under the thin covering of the luminous organ than under the heavy chitinous layer on the rest of the body. They do not assemble to send sensory hairs through the covering of the luminous organ, as they do under the other parts of the shell.

Immediately under the hypodermis of the central part of the organ are to be seen the actual luminous cells. These form a strong regular mass about eighteen to twenty-six cells deep. Their size averages about 75–150 microns in diameter when rounded, but they show a strong tendency to become elongate in a proximo-distal direction. For the most part they are closely massed together and moulded to fit each other's forms but at some points they show a slight tendency to form strings or rows, several cells wide, that reach from the surface inward.

The cell is provided with a large round nucleus and its cytoplasm is dense and dark staining with most chromatic stains. Two sorts of structures are to be seen in this cytoplasm: First, a certain number of large clear vacuoles that are placed around the edge or in groups in one end of the cell; secondly, very fine branching channels that may run centripetally from the edge toward the nucleus or may appear to enter the cell at one end and run through most of its length. They remind one somewhat of the trophospongia except that they reach the surface of the cell and sometimes appear to leave it. Fig. 6 shows a portion of one of these cells under high magnification.

The cytoplasm seems to owe its dense compact nature to masses of closely packed granules which fill every part of it. These give it its staining power and undoubtedly are the secretion particles of luminous material spoken of as luciferine or photogenin. In size they are much smaller than those shown by the various lampyrids. Heinemann has teased out these cells both with and without the addition of water and describes the contents as of two kinds, a smaller, hard, sharply outlined set of granules and larger droplets of an oily material.

The smaller granules show a decided brownian or molecular motion when discharged by a pressure of the cover-glass. Also, they then appear in two forms, the new one larger and apparently softer than the first, but without any more decided refractive properties.

The larger masses are globular like an oil and show strong surface tension and decided refraction of light which seems to determine them as an oil. When water is added the smaller two forms of granule soon swell and dissolve, which is not true of the larger ones. The nerves and air tubes of the luminous layer will be spoken of later.

Proximal of the luminous layer comes a layer of cells that form the reflector of the organ. This layer is somewhat thinner, especially in its middle, than the luminous layer, but it becomes nearly as thick at its outer edges. It is far wider than the luminous plate and its edges reach up around the ends of the latter and come in contact with the hypodermis and cuticle near the outer edge of the organ. It is at this point too that the dense black pigment is found on the cuticle.

The cells of this mass are singularly like those of the luminous layer in many ways. They are massed in much the same way and are of about the same shape. In size, however, they are a little larger while the nuclei are possibly a trifle smaller, although these nuclei vary in size to a much greater degree than in the case of the luminous cells. There are no vacuoles and no channels in the cytoplasm. The cytoplasm of these cells is filled with granules which we must consider as the reflective material of the layer. These granules are so like those found in the lampyridæ which have been carefully studied that we may assume for the present that they are of the same constitution, some form of a calcium urate. Here again Heinemann has made some careful studies that give us a good idea of their structure and chemical constitution.

Heinemann cut out the larger abdominal light organs of 186 large *Pyrophorus* and reduced them to an ash in a slow oven.

He then extracted with distilled water and again heated the insoluble remainder. The water-extracted solution was treated with hydrochloric acid, and bubbles, of carbonic acid gas probably, were given off. Further analysis showed traces of chlorine, phosphoric acid and potassium.

The unsoluble ash showed a mixture of calcium urate and potassium urate. Heinemann studied fresh reflector cells and notes the presence of two kinds of bodies in its cytoplasm. One of these is a non-crystalline granule and he identifies this as the calcium urate. The other is a smaller crystalline granule which he supposes to be the potassium urate. He attributes the phosphoric acid to some of the contents of the light cells and to the nuclei of all cells.

Heinemann was unable to see cell walls or nuclei in the reflector layer. This was due to the imperfect methods of his time and, as has been indicated, they are as easily seen and described as any other cells in the organ in properly cut and stained sections.

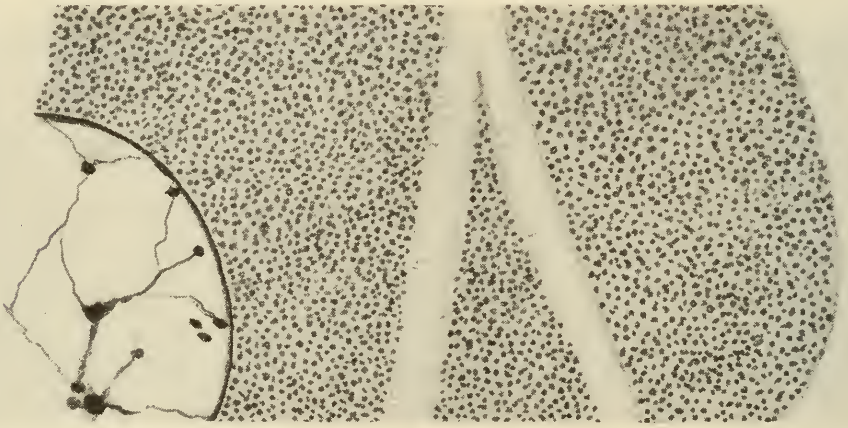
The writer has attempted to devise certain fixations and stains that would serve to determine a substance as luciferine or photogenin or not when this substance was being sought in an organ of unknown location in an animal that had been seen to light but whose light organs had never been described. Some of this work was tried on *Pyrophorus* and some ability was developed here to quickly show the granules of luciferine. This work is not of an exact chemical nature but purely rule of thumb to determine the presence of the material. In material fixed in Bouin, if eosin is used or a similar acid dye the luciferine granules take this dye very deeply. This method is not very diagnostic, however, as a large number of other materials also take it.

If the tissue is fixed in Flemming's fluid we get no very marked ability to distinguish the luciferine. But if hot Flemming's fluid is used and this is followed by an iron hæmatoxylin stain the granules of luciferine or photogenin come out quite black and can be differentiated from nearly all other substances in the body.

Thus Fig. 6 shows a small portion of the cytoplasm of a light cell in *Pyrophorus* stained in this way and exhibiting the small dark granules of light producing material. These granules remain and burn *in situ* and are undoubtedly in contact with the second substance or assisting medium while they do not burn and give off light solely on account of a lack of oxygen.

The light is produced as a long flash or more steady glow by the admission of atmospheric air through the tracheoles that form a network through the tissue. These tracheoles are ultimate branches of the trachea that are formed of tube-like invaginations of the hypodermis and its attendant cuticle from several points on the sides of the body. The walls of the resulting ingrowing tube retain both the hypodermis in a flatter form and the cuticle as a much thinner secretion of this hypodermis. In order that the tube of the chiten and its branches may be thin and yet not collapse when the expiration of air takes place, it is lined by circular or spiral thickenings or tænidia which serve to keep it round in form. Larger branches of these trachea come to the luminous organ when they form a mass of good-sized tubes directly behind it. There are reservoirs as well as conductors of the air and they give off numerous finer branches that pass down through the reflector layer and terminate in the luminous layer. They terminate by branching into a few long thin tracheoles that wind about between the light cells. These tracheoles have no tænidia but are long and smooth on the inside. They serve to carry the oxygen of the air directly to the light cells and their granules. No special structures mark the final branching of tracheal tube into tracheal capillaries. It is certain, however, that an unusually large amount of oxygen escapes into the tissues at that point, as is shown by forcing the insect to breathe osmic acid vapor, which also leaves the air passage through its thin walls at that point and blackens the surrounding tissue. Fig. 7 shows a section through this point.

FIG. 6.



Portion of a light cell of *Pyrophorus* under high magnification, a part of the nucleus is shown and the granules of photogenin.

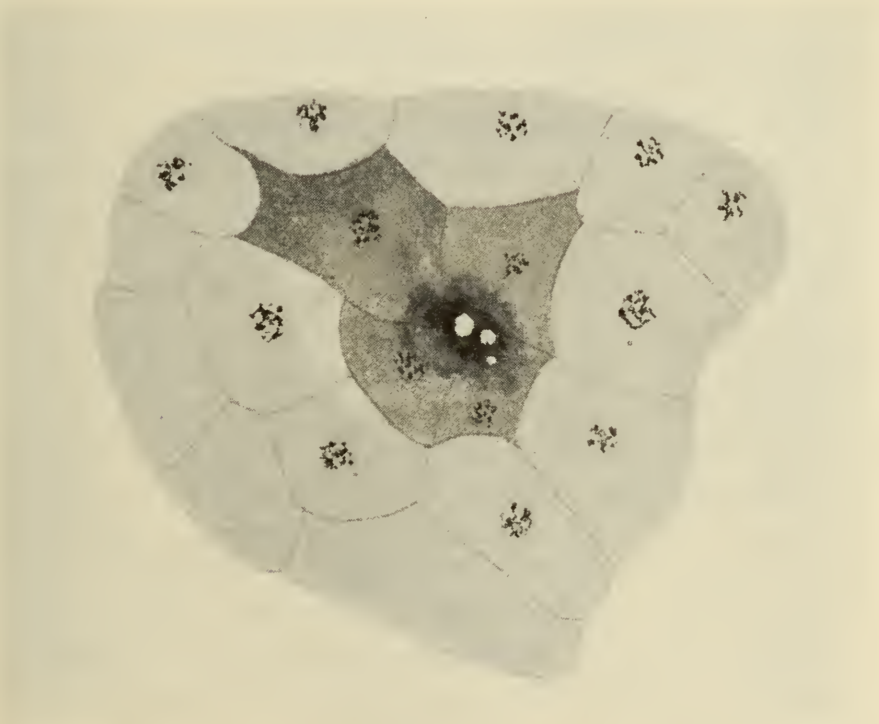
No very important chemical work has been done on *Pyro-*

phorus with regard to the chemistry of the light process and that will be left until the chapter on the lampyridæ.

Pyrophorus noctiluca lays its eggs shortly after mating and deposits them in dead wood and humus, according to Dubois who has studied their habits. Later observers assert that the eggs are always laid around or near the roots of the sugar cane on which the larvæ feed. This may be true of another species.

The eggs are luminous even before they are laid, as Dubois has described, and this light is weak and appears to come from all parts of the egg substance. When fertilized and laid they are still giving forth light. This light is not intermittent as in the adult, but is a weak, steady glow such as has been described in the bacteria and fungi. It was thought by some writers that the light came from the outside of the egg and that it was derived from some portion of the parent beetle's abdominal organ, but any knowledge of the insect's anatomy would easily show this to be impossible.

FIG. 7.



Section through branching tracheole at point where tracheal capillaries are given off. Dark cells have been stained by breathing of osmic acid. After Geipel.

The light evidently emanates from the cytoplasm of the unicellular ovum and represents a function of the organism that is not only already present in the one-celled stage, but one that exists in the cytoplasm of that egg and is already sufficiently differentiated to be operative at this early period. Such a delicate indicator might be of great use in studying the development of the organism and its differentiation.

As development proceeds the light gets fainter and we have no careful studies as to its intermediate fate. But just before hatching it is still visible and as the tiny larva crawls from the egg, the light is seen to come from a point inside the body and just behind the head. This observation cannot be doubted in the case of so well-known and skilful observer as Dubois. We now must mention the observations of a number of less well-known men on the subject. Many have asserted that the larvæ of several *Pyrophorus* species are without light. This may be true of some other species than *P. Noctiluca* but it is certainly not true of this kind. Others have described, insufficiently, certain luminous bettle larvæ that certainly were not *Pyrophorus.* Some of them were probably *Phengodes* larvæ or adult females and others were doubtful.

Returning to Dubois's observations we learn that the single anterior light persists through the first stage and in the second stage it is still there, but in addition he was able to see a number of other light organs in operation. The first eight segments of the abdomen showed each three brilliant spots of light, one median in position and two lateral. The body of the larvæ was translucent and Dubois said that the median lights appeared dimmer than the lateral ones and might have been a combined reflection of the other two on the shining chitenous wall of the body. This could easily be settled by sections which apparently were not used.

Dubois figured parts of a section of the single anterior light and from these figures it would appear that the structure was much the same as that of the adult organs. It was composed of a bilateral mass of cells about the intestine and these cells contained bi-refractive granules of some size.

A section through one of the posterior segments shows the two lateral organs as masses of cells held in a rounded evaginated pocket of the cuticle. No intimation of a separation into reflector and luminous layers is given and as the lower median portion of the section is missing one can make no surmise as to the presence or structure of the median organ of the segment as mentioned above. It seems probable that one was present.

INDEPENDENT LABORATORIES IN THE ENGINEERING INDUSTRIES.*

BY

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Member of the Institute.

The importance of laboratory work in connection with our national industries is coming more and more to be recognized, and there is no little discussion at the present time of suitable ways and means for promoting it. With the sharpened competition which must ensue at the close of the war which is now paralyzing the peaceful industries of the world, any and all means for increasing our industrial efficiency will be considered with a seriousness which in the easy-going times of the past has not been accorded to them.

Our great manufacturing organizations are for the most part quite awake to the fact that laboratory testing and research are necessary and indispensable adjuncts to the growth and development of their industries. They realize that it is to the laboratory that they must look for radical or fundamental advances in the materials, methods and processes of production. They have established splendid laboratories and have attracted to them some of the greatest scientific men of the country. The product of these laboratories has been of enormous value—a value which cannot be measured in money, for it includes engineering and scientific discoveries which become the permanent possession of the human race and add to the prosperity and happiness of all future generations.

The manufacturers of smaller resources do not, however, make a correspondingly large use of laboratory assistance. This may be ascribed to two causes: first, that they are not so fully aware of their own need for laboratory assistance and of the possibilities of laboratory work in increasing their efficiency, bettering their product and broadening their scope; and second, because of practical difficulties in securing such laboratory facilities as correspond to their needs. It is with the latter phase of the situation that this paper is intended primarily to deal.

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*Communicated by the Author.

Laboratory or research work is commonly divided into two classes, both of which are important in connection with our national industries. First, there is the work in pure or academic science—the work primarily of the university. Second, there is the work in applied science, or in industrial research. Dr. J. J. Carty [1] in his address as President of the American Institute of Electrical Engineers, has very clearly and very aptly drawn the distinction between research in pure and in applied science when he said that it lies neither in the subject matter, which may be identical, nor in the methods, which may be the same, but in the motive. To quote his words:

"Industrial research is always conducted with the purpose of accomplishing some utilitarian end. Pure scientific research is conducted with a philosophic purpose, for the discovery of truth, and for the advancement of the boundaries of human knowledge.

"The investigator in pure science may be likened to the explorer who discovers new continents or islands or hitherto unknown territory. He is continually seeking to extend the boundaries of knowledge.

"The investigator in industrial research may be compared to the pioneers who survey the newly discovered territory in the endeavor to locate its mineral resources, determine the extent of its forests, and the location of its arable land, and who in other ways precede the settlers and prepare for their occupation of the new country."

Evidently the industrialist who, to carry the analogy further, may be likened to the settler in the new territory, is dependent upon both classes of investigator; on the investigator in pure science because it is he who indicates the existence of a field heretofore unknown; on the industrial investigator because it is he who discovered the commercial possibilities which the field contains.

The organization which is pre-eminently fitted to carry on the primary work of pure scientific investigation is the university. It is to the university that we must look to discover and to foster the men having those rare and peculiar gifts of imagination, of transcendent patience, of unselfish devotion, which go to make up the explorer into the unknown regions for the extension of physical and chemical science. It is the university which must furnish these men the surroundings and the facilities which are required for the prosecution of their work.

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[1] Carty, Proc. A. I. E. E., vol. xxxv, p. 1411, Oct., 1916.

For the adequate pursuit of industrial research work, however, it is necessary to look to organizations constituted differently from the university. Industrial research having as its end the accomplishment of a definite result of commercial value accruing primarily only to the promoter of the work, it is evident that an institution organized like the university primarily for an educational purpose, and supported largely by endowments or by public funds, cannot justly devote any considerable portion of its energy or of its resources to any purpose which is not for the benefit of the public at large. The technical schools in this respect are in the same class with the universities, with the important exception that a technical school is in general better situated for the conduct of industrial research work than is the university from the fact that its training is along industrial lines. Hence we find that many of the great industrial corporations in this country have, as has been said, met their own needs by establishing their own private industrial laboratories. For the industries at large, however, this affords no adequate solution of the laboratory problem, for it does not apply to the multitude of concerns, individually smaller than the great corporations and unable each by itself to support economically and efficiently an adequate laboratory, but in the aggregate of enormous industrial importance. The importance of laboratory work to the smaller concerns is relatively just as great as to the larger ones, and the problem is, the best means of supplying their needs in this particular.

One possible solution is for the smaller manufacturer to take his laboratory problems to a technical school for solution. This plan, while it may work out admirably in many cases, is open to the objection which has been mentioned above, namely, that the funds of the institution, being given for a public purpose, should not be diverted to private ends. However, it may be urged against this that it is to the advantage of the technical school to take on a certain amount of industrial work, not only in research but also in testing. Such work necessarily brings both instructors and students into contact with certain practical problems of the outside industrial world, a world of which they know much in theory but too often but little in practice. The effect of this contact cannot but be broadening and helpful to the technical school and to its students, and if this advantage is sufficiently substantial, the theoretical disadvantage of diverting the attention and the resources of the institution to a limited extent to matters which are particularly the affair of private outside individuals or corporations is more than counterbalanced. Added to this advantage to the technical school are certain others, among which may be mentioned that incidentally the frequently inadequate salaries of the body of instruction in the technical school are to some extent augmented and the instructors thereby put into a position more nearly in accord with the demands which are made upon them. To the industrial concern a recourse to the laboratory of a technical school may offer the advantage of furnishing a service for a smaller expenditure than would be necessary if all of the overhead and incidental charges were included, which under similar circumstances a commercial organization would have to make.

As against the advantages so outlined there are certain disadvantages which must be given careful consideration and due weight. We have noted that taking on a piece of industrial work has the effect of bringing instructors and students into contact with practical industrial problems and thereby broadens their vision and increases their usefulness. To the industrialist, however who has a problem to solve, the very lack of contact with the actualities of practice very greatly lessens the value of the technical school as an organization for the accomplishment of his purpose. Every technical problem is surrounded by limitations and special conditions which may not from an academic standpoint appear to be of controlling importance, but which if not given their practical weight render any solution nugatory. Considerations of cost, of the intellectual and psychological limitations of workmen, of transportation, or market conditions, of company policy, of technical and commercial usage in the field—any or all of them may have their influence on the result. The technical school men, if less in touch with practice, are evidently at a disadvantage in the solution of problems involving these elements. The technical school, being organized and equipped for purposes of education and not for purposes of testing or industrial research, is frequently at a disadvantage on account of the limitations of its laboratory equipment, the amount of power, etc., available, and on account of the lack of a business or technical organization especially designed to prosecute with directness, accuracy and engineering common-sense, industrial problems which it never was designed to handle. It must be remembered that while many discoveries are made by laboratory experiments on a small scale, many of these are not applicable to industrial exploitation for the reason that elements which in small-scale experimentation are of negligible importance, often become controlling factors when the scale is changed to correspond to practical production. A chemist in his laboratory may effectually close a flask with a cork; a similar procedure does not apply at all to a spouting oil well. He may evaporate to dryness a dilute solution for the purpose of recovering a small residue and never once think of the gas which he uses in the process. If he were dealing, however, with the same operation on a scale ten thousand times as big, the matter of fuel and of containing vessel might offer insuperable obstacles to commercial success. Small-scale experimentation teaches but little regarding the proper design of a switch to open a high-tension power circuit. Hence apparatus which is quite adequate for the small-scale work of the laboratory of instruction may be entirely inadequate when experiments are required looking toward the industrial application of a process.

In speaking of this feature of industrial work in educational institutions, Dr. Steinmetz [2] in a recent address said:

"Unfortunately this limitation of research work in accordance with the available facilities is not always realized, and especially educational institutions not infrequently attempt research work, for which industrial laboratories are far better fitted, while research work for which the educational institution is well fitted, which the industry needs but cannot economically undertake, is left undone."

Prof. James Swinburne [3] in a lecture on Science and Industry, delivered very recently at Kings College, has pointed out that the instructor in technology tends as times goes on to be less and less in touch with practical conditions and more of an academic scientist. This is for the reason that in general only those who have less taste for engaging in the practical work of industry are likely to take up the teaching profession, and their own successors are as a general thing the less practical ones of their own students. The academic scientist, on the other hand, is a master of his subject, for his science, like himself, is academic, and in his own field he is pre-eminent. Thus the tendency of the technologist to become academic is a tendency for him to follow his own proper bent and to employ his energies in the direction in which they will be most effective.

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[2] JOURNAL OF THE FRANKLIN INSTITUTE, vol. 182, p. 711, December, 1916.

[3] *The Electrician*, London, vol. lxxviii, p. 182, November, 1916.

Since to refer the problems of the industry to the technical schools for investigation does not offer a satisfactory solution of the problem, some other way out must be sought. This may be found along the lines indicated by Dr. Carty when he said:

"One of these is for the manufacturer to take his problem to one of the industrial research laboratories already established for the purpose of serving those who cannot afford a laboratory of their own. Other manufacturers doing the same, the financial encouragement received would enable the laboratories to extend and improve their facilities so that each of the small manufacturers who patronizes them would in course of time have the benefit of an institution similar to those maintained by our largest industrial concerns.

"Thus in accordance with the law of supply and demand, the small manufacturer may obtain the benefits of industrial research in the highest degree and the burden upon each manufacturer would be only in accordance with the use he made of it, and the entire cost of the laboratories would thus be borne by the industries as a whole, where the charge properly belongs."

Thus to the independent laboratory is assigned an important place in the engineering industries as providing for the smaller manufacturer laboratory facilities comparable with those enjoyed by some of the great corporations. To fulfil properly these functions the independent laboratory must be adequately supported, properly manned and abundantly equipped. Its staff must be organized on broad lines. Its engineers must be familiar with the practical and commercial features, as well as the technical details, of the work which they encounter. It must include physicists and chemists accustomed to look at the fundamental features of the problems presented and to bring to bear upon their solution the methods and the point of view which are inculcated in the university laboratories of research, for the application of fundamental scientific principles to the solution of the problems of industry underlies all true industrial research. The fees charged by such a laboratory must be adequate to cover not only all expenses, but to yield a sufficient profit as well, for:

" Unless industrial research abundantly supports itself, it will have failed of its purpose."

In return for the fees so paid it must deal with its clients in a highly confidential manner, conserving to them individually all of the results of the work for which they are paying. It must be prepared to turn over to its clients the inventions and patents which are the direct outcome of any specific piece of work. It must organize its work efficiently, so that its costs are as low as is consistent with good work and so that the results are obtained without undue delay. As to equipment, this undoubtedly must be large. The variety of problems which a laboratory of this sort will have brought to it will be of such scope that a great variety of instruments for measuring and for manipulation must be at hand. A very large supply of electrical power is an absolute requisite. These conditions interpose serious obstacles in the way of the establishment of laboratories of this character. Unless the laboratory is organized through the coöperative efforts of a considerable number of industrial corporations operating in the same or in similar fields, a difficulty is sure to be encountered in insuring beforehand its proper support. To some extent a laboratory of this sort must from its very inception possess an equipment representing a very considerable investment. Unless therefore the financial support is insured beforehand, no little faith is required on the part of those investing their money in it. When, however, it has been possible to establish a laboratory of this character, the scope of its work may be very large. It may, and should, include not only industrial research proper, but ordinary and routine testing, such as is required not only by manufacturing concerns, but also by consulting engineers and others. It should be prepared to make acceptance tests of manufactured articles on behalf of purchasers and a considerable part of its activities may lie in this direction. It should offer facilities to engineers, inventors and other would-be experimenters to carry on laboratory work of their own under its roof, and should make available to them all its own facilities. In carrying out work of this great scope in an adequate and proper manner the independent laboratory will find itself side by side with the technical school as one of the potent factors of industrial progress. The staff of such a laboratory will become increasingly efficient through the practical solution of problems of many kinds. The apparatus and other equipment will necessarily take on a diversified character such that new and unusual problems presented can be undertaken without the purchase or construction of special apparatus. As compared with under-equipped and insufficiently manned laboratories which with a most laudable spirit individual manufacturers may establish for their own use, independent laboratories, supported by formal or informal coöperation, should be far more efficient both as regards the cost of maintenance, the character and extent of the equipment, and as to the practical results to the industries, because of the product of the researches conducted therein. In the last analysis the availability and utility of such laboratories depend on the amount of material support which the industrial world is willing to accord to them.

A Method of Comparing Automobile Performance. W. T. FISHLEIGH. *Society of Automobile Engineers' Bulletin,* vol. xi, No. 2, November, 1916.)—The problem of analyzing automobile performance is not a new one and much has been written and argued upon the subject. The demand is widespread for a standard interpretation for performance and a method of determining it. Numerous formulas have been proposed. In most cases these are efficiency formulas, designed for estimating from certain known dimensions the probable performance or performance factors. In no case are all these factors included that seem critical in performance; in several cases serious inaccuracies can be pointed out when their application to actual road performance is attempted.

Automobile performance should be determined by actual tests, and *speed range, acceleration, fuel economy* and *riding comfort* are the factors for such determination. The first three of these factors are susceptible of measurement by accurate tests and the product of such factors would result in a satisfactory criticism of performance. It has been pointed out, however, that in taking the product, the identity of each one is entirely lost, and for purposes of comparison the limits rather than the maximum of these three factors should be separately considered as the three dimensions of car performance. The factor of riding comfort is one that scarcely admits of definite numerical expression.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

STANDARD SUBSTANCES FOR THE CALIBRATION OF VISCOMETERS.[1]

Eugene C. Bingham and Richard F. Jackson.

[ABSTRACT.]

FOR the purpose of the calibration of viscometers there is a need for one or more liquids of viscosity greater than water which can be easily obtained in pure condition and whose viscosity is known with a considerable degree of certainty. The substances selected, besides water, were mixtures of ethyl alcohol and water, and sucrose and water. Previous work upon water and alcohol was adequate and consequently the experiments were confined to the sucrose and water. The sucrose was purified by repeated recrystallization from water solution and contained residual impurities of the order of one-thousandth of a per cent. The solutions used in the measurements were analyzed by determination of density and by polariscopic test.

The viscometer used in the investigation consisted essentially of a U-tube fitted with a capillary on one limb surmounted by a bulb with constrictions which could be used to measure the volume of liquid. A bulb of similar size and shape was sealed on the other limb. The viscometer was connected to a manometer and pressure apparatus for the application of pressure. From the observations the viscosity was calculated by the usual formula

$$\pi = C\ p\ t - C'\ \rho/t$$

in which p is applied pressure, ρ density of liquid, t time of flow, C and C' constants abbreviated from the complete viscosity formula. C' was found by direct calculation, C by measuring the time of flow of pure water at 20° C. and substituting its viscosity 0.01005.

The viscosity was measured at a variety of applied pressures. To obtain the true effective pressure, the height of liquid in the manometer is corrected for air buoyancy, column of connecting

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* Communicated by the Director.

[1] Scientific Paper No. 298.

air and hydrostatic head of the liquid undergoing measurement. In order to be certain that the drainage of solution was complete the time of flow required to discharge and to fill the bulb was measured. Furthermore, viscosity was found to be independent of applied pressure. To test calculations and corrections the viscosities of water were measured, using a considerable range of pressures. The value was found to be constant.

In order to avoid the arbitrary scales of commercial viscometers and the inconvenient magnitudes of the absolute units, we suggest the use of the "centipoise" as a unit of viscosity. This is one-hundredth part of the C. G. S. absolute unit. The centipoise is almost exactly the viscosity of water at 20° C. (1.005) and, hence, is at the same time the specific viscosity of any substance referred to water at very nearly 20° C.

The viscosities of water have been determined by several investigators. The existing data has been reviewed in order to correct it so far as possible according to our present knowledge. The mean values expressed as fluidities may be expressed by the formula:

$$\phi = 2.1482 \left\{ (t - 8.435) + \sqrt{8078.4 + (t - 8.435)^2} \right\} - 120$$

in which ϕ is fluidity and t centigrade temperature.

Mixtures of ethyl alcohol and water may be used as standards. Their fluidities expressed as functions of temperature and weight and volume percentage of alcohol accompany the complete article.

The viscosities of a 39.99 per cent. sucrose solution were measured at temperatures varying from 0° C. to 95° C. The observed values corresponded to the formula:

$$t = 0.597\ (\phi + 20) - \frac{1438.6}{\phi + 20} + 38.24.$$

Inasmuch as some discrepancy was found to exist between this and former values the experiment was repeated and practically the same values were obtained.

The measurements were then made on 20.007 per cent. and 59.96 per cent. sucrose solutions. The fluidities at the latter concentration corresponded to the formula:

$$t = 1.472\ (\phi + 5) - \frac{323.2}{\phi + 5} + 58.62.$$

The values found in the present investigation indicated a higher viscosity than those of previous investigators.

THE MANUFACTURE AND PROPERTIES OF SAND LIME BRICK.[1]

By Warren E. Emley.

[Abstract.]

Sand lime bricks are made of sand and lime, hardened by exposure to the action of steam at high pressure. They compete in numerous localities with common building bricks made of clay. There is a widespread demand for information as to just what sand lime bricks are, how they are made, and what properties one may expect them to have. In this paper an attempt has been made to compile this information and make it accessible. A short theoretical discussion leads to certain conclusions as to the desired properties of the raw materials—sand and lime. The different steps of the process of manufacture are then taken up in detail, and comparisons made of the different mixing, pressing, and hardening operations as carried on in various factories. The testing methods generally employed for the examination of common building bricks are described in detail, and a summary is given of the results obtained when sand lime bricks are subjected to these tests. An appendix contains detailed descriptions of the equipment of seven typical factories.

THE RESISTANCE OF AN OIL TO EMULSIFICATION.[2]

By Winslow H. Herschel.

[Abstract.]

In forced feed lubrication, such as is used with high speed engines and turbines, there is often trouble due to the emulsification of the oil. Service tests are not practicable, on account of the time and trouble involved, so that there is great need of a laboratory test. Moreover it is highly desirable that the test should make it possible to express the resistance of an oil to emulsification by a single numerical value, as experience has proved that it is almost impossible to enforce in a contract any less definite specification.

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[1] Technologic Paper No. 85.

[2] Technologic Paper No. 86.

A study of the literature showed that though several emulsification tests were described, they were all more or less indefinite, and no one of them was in general use. It was therefore necessary to devise an entirely new test, which may be briefly described as follows:

Twenty cubic centimetres of the oil to be tested, and double that volume of distilled water, are heated to 55° C. (130° F.) in a 100 c.c. cylinder, 26 mm. (one inch) inside diameter, and stirred for five minutes at a speed of 1500 r.p.m. The paddle is simply a plate of metal, 89 by 20 by 1.5 mm. (3½ × 13/16 × 1/16 in.) approximately. Since the test is not sensitive to slight changes of paddle dimensions, they need not be exact, and no calibration is required. The cylinder, and contents, are allowed to stand at the same temperature and readings are taken at more or less frequent intervals (according to the type of oil) of the volume of oil settled out from the water. From these readings, a maximum rate of settling, called the "demulsibility," is easily taken from a table.

A German test, used for steam engine cylinder oils, would appear at first sight to discriminate against the good oils containing compounding, in the attempt to eliminate the poor oils which contain soap. Examination of the experience with the test, however, shows that the method of agitation is not very effective, so that only oils which contain soap will emulsify. Good oils, even if they are compounded, will not emulsify. The test here described might be so modified as to make it applicable to steam engine cylinder oils, but this has not yet been attempted, and in considering the results obtained with the test for demulsibility, compounded oils have been omitted, except where noted.

It has been found that the majority of oils on the market are either very good or very poor. The best transformer, dynamo and turbine oils settle out in a minute or less, thus showing a demulsibility of 1200 c.c. per hour, which is the highest value on the arbitrary scale adopted. On the other hand, when an emulsifying marine engine or crank case oil is tested, no oil will settle out of the emulsion up to the end of the hour that the test is continued, and the demulsibility is recorded as zero.

Comparison with chemical tests shows that the stirring tests are the more sensitive, and this is in agreement with the experience of others. This explains why it is has been such a troublesome problem to chemists, why one oil would emulsify and the other would not, when according to their tests both oils were equally pure. The stirring test shows that a minute amount of impurity, which cannot be detected by chemical means, will cause a marked increase in emulsification.

Oils which have a suitable demulsibility will not emulsify in use, but there is still the trouble that, after a considerable length of time, they may disintegrate and deposit sediment, due to oxidation, polymerization or some other similar chemical change. On this account an investigation of used oils was undertaken, and it was found that there was a marked decrease in demulsibility with continued use. The conditions of operation are so different in different power plants, that exact values cannot be given for the rate of deterioration to be expected, but it is believed that the test should prove of great assistance to power house engineers in keeping track of the deterioration of the oil in their plants.

STUDIES ON PAPER PULP.*

By W. H. Smith.

[ABSTRACT.]

SEVERAL paper pulps, each representing a different method of preparation and, with one exception, of American manufacture, have been examined to determine their chemical properties in terms of the amount of ash, cellulose, and methoxyl, the yield of furfural and methylfurfural, and the copper number. Using the same pulps, the loss in weight produced by reagents causing oxidation and hydrolysis, and the increase in weight on nitration, have been determined. The effect of sunlight, temperature, and active oxygen on the chemical constants obtained with ground wood has been ascertained.

Centrifugal versus Reciprocating Boiler Feed Pumps. M. W. EHRLICH. (*Electrical World.* vol. 68, No. 20, November 11, 1916.)—Many central electric lighting, heating and power companies are favorably considering the centrifugal pump with steam-turbine drive as an auxiliary in boiler operation. In the moderate unit, either motor or turbine driven compares favorably in first cost with reciprocating pumps. The centrifugal is compact and occupies a small floor space for a given capacity, and is therefore suitable where space conditions are important. In small sizes the centrifugal pump is relatively uneconomical, but in moderate sizes the economy compares favorably with that of a reciprocating steam pump.

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* Technologic Paper No. 88.

The centrifugal unit is of simple construction without air chambers or valves, and delivers a steady flow of water so essential to the accuracy of measuring instruments used in power plant operation. The operating and maintenance costs are low, but under conditions of fluctuating load requiring a variable pump speed, the economy is poor and the reciprocating pump will be found preferable. While practice has shown that for central station power plant service the steam turbine driven pump is most reliable, and that motor driven pumps are advisable as duplicates or relays, it is still a debatable question whether centrifugal pumps for boiler feed are desirable in plants of less than 3000 boiler horsepower and 125 pounds pressure. The minimum size of installation seems to be a 250 gallon per minute unit operating against 300 feet total head requiring a 40 horsepower electric motor or steam turbine, the pump being a three-stage unit.

Magnetic Properties of Iron-Cobalt Alloys H. F. KALMUS AND K. B. BLAKE. (Canada Department of Mines, Mines Branch, Report No. 413, 1916.)—Iron-Cobalt alloys approximately to the composition Fe_2Co are produced in sound ingots only with difficulty. While fairly strong, the alloy is brittle, though annealed samples show approximately the same tensile strength as pure iron. It may be forged with considerable readiness, after which it has nearly twice the strength of pure iron. The magnetic properties of the alloy, however, should render it of great value in parts of electromagnetic apparatus where extreme magnetic densities are required. Its high magnetic saturation value is readily observed by the simplest test with a hand magnet, that is the hand magnet will lift considerably heavier pieces of the alloy than of pure iron.

The best castings have a saturation value of 10 per cent. to 13 per cent. higher than that of pure iron. Their maximum permeability is 13,000 at a density of 8000 gausses. This is considerably lower than the corresponding value for pure iron, but much greater than that for standard transformer steel and other commercial materials. The hysteresis loss of the alloy is less than for the best grades of commercial transformer steel at densities of 10,000 gausses, and about the same as for commercial transformer iron at the corresponding densities, at densities of about 15,000 gausses. The specific electric resistance is about 10 microhms. The most important property of the alloy Fe_2Co is its permeability in medium fields. Through the range of magnetizing force of 50 to 200 gilberts per square centimeter, the permeability is approximately 25 per cent. greater than that of pure iron or of commercial grades of transformer steel or iron.

NOTES FROM THE RESEARCH LABORATORY, EASTMAN KODAK COMPANY.*

THE OPTICAL PROPERTIES OF LIGHT FILTERS.[1]

By C. E. K. Mees.

[Abstract.]

In discussing the optical properties of light filters for use in photo-engraving and color processes, the subject is divided by the author into two parts: (*a*) the optical properties of perfect filters; (*b*) the optical properties of imperfect filters. Under the first division, mathematical expressions are given for the two principal aberrations suffered by light in passing through a plane parallel filter, namely, curvature of field, and spherical aberration. Numerical application is made to the most unfavorable case occurring in practice. The results found prove that no detrimental or even sensible action occurs. Difference in magnification due to the use of filters of different colors is next considered. It is found that for red and blue filters the difference is of the order of one part in five thousand, or negligible. Compensation for this can be secured by making the filters of slightly different thicknesses. In testing imperfect filters, the author made use of a telescope of long focal length, and a test object formed of illuminated squares. Photographs of the appearance of the image with imperfect filters interposed are given. The effects of poor grade glass, cylindrical curvature, and cell pressure are shown. In examining high grade filters, a resolution test is used. Finally formulæ for change in magnification due to filters of different thickness, and to filters having spherical boundary surfaces forming a lens of power dP, are deduced, and verified by means of actual tests in a specially designed optical apparatus.

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* Communicated by the Director.

[1] Communication No. 41 from the Research Laboratory of the Eastman Kodak Company.

Efficiency of Propulsive Machinery and Developments in Naval Engineering. H. C. DINGER. (*Proceedings of the American Society of Mechanical Engineers,* December 5–8, 1916.)—Reports made in 1912 on the relative performance of turbine-engined and reciprocating-engined naval vessels indicated the superiority of the latter for battleship propulsion. Trials of vessels constructed later, however, showed that the real cause of this superiority of performance lay in the faulty design of turbines and propellers. In tracing the advance in economy in turbine propulsion, as good examples of modern practice, the reciprocating-engined vessels, *Delaware, New York, Oklahoma,* the Parsons-turbine-engined vessels *Utah* and *Arkansas,* and the Curtis-turbine-engined vessels *North Dakota, Nevada* and *Pennsylvania* are selected.

So far as economy at different speeds is concerned, it is shown that there is but slight choice between the different types of machinery when they have the proper propeller efficiency. At very low powers the reciprocating engine is about as economical as the geared cruising turbine, and both of these are more economical than the directly connected cruising turbines; and it is evident that matters other than economical performance should decide the question of type of prime mover. When losses are guarded against it is the range of temperature that really counts in securing efficient propulsive machinery; hence the most effective measures are obviously the use of superheat and the highest practicable vacuum, the best possible utilization of freed-heating apparatus, and the economical operation of auxiliaries. The latter can become very wasteful, but in the best cases the percentage of available heat used by them has been reducd to about 5 per cent. of the total fuel power.

The geared turbine and electric drive are recent innovations which show decided economy and a material saving in weight over directly connected units. For large capital vessels the electric drive is to be preferred on account of (1) greater flexibility in shaft and piping arrangements, (2) better economy at cruising ranges, (3) better arrangement of generator rooms, boilers, etc., (4) better handling conditions and greatly improved power for backing, and (5) the practicability of using high superheat; also (6) parts of machinery can undergo repair while other parts are in operation at a very large percentage of the total power of the vessel. In general terms, the problem of the naval engineer is largely one of saving weight and space, and the principal method of accomplishing this is to install high-efficiency machinery and to enlist the co-operation of the industrial engineers of the country.

NOTES FROM RESEARCH DIVISION, ELECTRICAL ENGINEERING DEPARTMENT, MASSACHUSETTS INSTITUTE OF TECHNOLOGY.*

A RESEARCH on "Tractive Resistances to a Motor Delivery Wagon on Different Roads and at Different Speeds," by A. E. Kennelly and O. R. Schurig, has recently been issued from the Electrical Engineering Department of the M. I. T., as its Bulletin No. 10. It is a reprint of a paper read before the American Institute of Electrical Engineers in June last. The research was carried out in and near Boston in 1915–1916, under an appropriation from Mr. Thomas A. Edison, and also from the Gould Storage Battery Co.

Measurements of tractive resistances of various kinds of vehicles have been made and recorded for many years; but the methods of analyzing and presenting the results as contained in this report, appear to be new, and have certain advantages. The authors define the tractive resistance of an electrically self-propelled vehicle, on a level road, in the absence of wind, as the horizontal force which, applied to the vehicle at the actual steady running velocity, would develop a power equal to the battery output after deducting from the latter all losses in the motors, gear, and internal car-wheel mechanism; *i.e.,* all losses from battery terminals to wheel spokes. The horizontal pull overcomes the resistance of the tires and roadbed, as well as the resistance of air displacement. It may be expressed either in kg. per metric ton of total vehicle weight, or in equivalent grade. A tractive resistance of 1 per cent. equivalent grade means, therefore, that the tractive effort which must be applied to the vehicle, on a level road, to overcome tire and road resistance, as well as air resistance, at a given speed, would suffice to drive the same vehicle at that speed up a 1 per cent. grade, in the absence of all resistances of air, tires and roadbed, as well as of all internal frictions, such as those of axle, gears, and driving motor.

The vehicle on which the tests were made was a 450 kg. (1000-lb.) electric truck, weighing from 2140 kg. to 2400 kg., with solid rubber tires and running at speeds from 13 to 25 km. per hr. (8 to 15.5 miles per hr.). The results indicate that on smooth roads, the road-and-tire resistance is constant over the above range of speeds; and varies from less than 1 per cent. equivalent grade (0.85 per cent.) on the best hard roadbed, to 1.6 per cent. on smooth soft roadbeds. On rough roads the tractive resistance increased with the speed, owing to impact. The additional resistance due to impact was greatest on the roughest roads. At 20 km. per hour, the air-displacement resistance of the truck was a little over one per mil grade (0.1 per cent.). The total range of equivalent grade of tractive resistance encountered in the tests was from 0.93 to 2.7 per cent.

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* Communicated by the Director.

Long Life Tungsten Lamp. ANON. (*Electrical World,* vol. lxviii, No. 17, October 21, 1916.)—It is well known that when a tungsten filament is operated in an evacuated bulb under ordinary conditions, the resistance of the filament gradually increases, thus lowering its temperature, and the bulb is progressively darkened by a black deposit of vaporized tungsten. Both these effects contribute to lower the efficiency and candle-power of the lamp. Heretofore, in order to increase the life of a lamp at a given efficiency, various solid halogenous compounds of low vapor tension, such as potassium iodide, have been placed in the lamp. These compounds are placed in the lamp in such a position that when the filament is at normal incandescence and the bulb is well evacuated there is evolved an atmosphere which is chemically active to the metal of the filament at substantially the pressure of a high vacuum.

Roy Winne of Schenectady, N. Y. (patent, No. 1,197,705), has discovered that the useful life of a lamp may be further increased by placing in the bulb with a regenerative compound of the above nature a very small amount of gas, preferably nitrogen. Ordinarily, the pressure of the gaseous atmosphere should be less than 100 microns, and usually within the range of about 10 to 50 microns, or 0.010 to 0.050 mm. of mercury. To illustrate the effect of the novel filling combination on the life of the lamp, a 125-volt, 100-watt lamp having a drawn tungsten filament was provided with a small amount of potassium thallium chloride placed in the same way as in a vacuum lamp. The bulb was evacuated, and then enough dry nitrogen was admitted to produce an atmosphere of about 25 microns (0.025 mm. of mercury) pressure. The lamp was then sealed off and operated at a specific consumption of 0.95 watt per candle. After 1900 hours the candle-power had fallen off only to 96 per cent. of its original value. During the operation of the lamp the resistance of the filament repeatedly increased several per cent., and then came back to normal. In the absence of the nitrogen the initial efficiency of a lamp of this type containing potassium thallium chloride would have fallen to about 80 per cent. in about 1000 to 1200 hours.

THE FRANKLIN INSTITUTE

(Proceedings of the Annual Meeting held Wednesday, January 17, 1917.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, January 17, 1917.

PRESIDENT DR. WALTON CLARK *in the Chair.*

Additions to membership since last report, 9.

Mr. Charles E. Bonine, Chairman of the Committee on Science and the Arts, reported the conditions of the work of the committee.

The tellers of the election, Messrs. Jennings, Colvin, and Picolet, submitted the report of the ballots cast for President, Vice-president, Treasurer, and members of the Board of Managers, and the following gentlemen were declared duly elected to the respective offices:

Walton Clark, President (to serve one year).

Coleman Sellers, Jr., Vice-president (to serve three years).

Cyrus Borgner, Treasurer (to serve one year).

G. H. Clamer, Theobald F. Clark, Walton Forstall, Benjamin Franklin, Harry F. Keller, Richard Waln Meirs, George D. Rosengarten, William C. Wetherill, Managers (to serve three years), Nathan Hayward, Manager (to serve two years).

The President presented a statement of the work of the Institute for the fiscal year ending September 30, 1916, with the Reports of the various Committees of the Institute and Board of Managers.

Mr. Charles E. Bonine, Chairman of the Committee on Science and the Arts, introduced Dr. Edwin Fitch Northrup, of Princeton, New Jersey, to whom had been awarded the Elliott Cresson Medal for his electric furnace and high temperature investigations.

The President presented the Medal and accompanying documents to Dr. Northrup, who thanked the Institute for the honour it had conferred upon him.

Harry Fielding Reid, C.E., Ph.D., Professor of Dynamical Geology and Geography, Johns Hopkins University, Baltimore, Md., presented the paper of the evening, entitled, "The Panama Slides." The speaker described the location and general character of the canal, devoting especial attention to the Gaillard Cut and the Culebra region. Consideration was given to the material of the slides and the encircling hills as well as the nature of the movement of the slides. The progress of the slides and the probable outlook for the future were also discussed.

After a discussion in which Messrs. Wetherill, Bond, Graham, Penrose, and others participated, the thanks of the meeting were extended to the speaker.

On motion of Mr. Penrose, duly seconded, the thanks of the Institute were extended to the tellers of the election for their services.

Prof. L. F. Rondinella called the attention of the members of the Institute to the fact that they were meeting on the anniversary of the birth of Dr. Franklin and referred to the wreath placed by the Poor Richard Club under the Sully portrait of Franklin to the right of the President's chair. He pointed out Franklin's claim to the appreciation of all Americans and especially of Philadelphians, and his importance in the history of our country was compared with that of Washington and Lincoln. The speaker felt that Franklin's birthday should be celebrated in a more fitting way, and that the University of Pennsylvania and the American Philosophical Society (both founded by Franklin) would be glad to coöperate in arranging such a celebration. Upon Prof. Rondinella's motion, duly seconded and carried, it was—

Resolved, That the President of the Institute be requested to appoint a Committee on Celebration of Franklin's Birthday to consist of three members of the Board of Managers. This committee to confer with similar committees that may be appointed by the University of Pennsylvania and the American Philosophical Society upon invitation of the Institute's secretary and to arrange for a joint annual celebration, and reporting its recommendations to the Board of Managers for action.

Adjourned.

R. B. OWENS,
Secretary.

REPORT OF THE PRESIDENT.

FOR THE FISCAL YEAR ENDING SEPTEMBER 30, 1916.

To the Members of The Franklin Institute:

Your Board of Managers instruct me to report to you upon the work of the Institute for the year ending September 30, 1916, as follows:

Your Board, in their report for the year ending September 30, 1915, made an appeal to the membership of the Institute for the completion of the so-called Wahl Fund; a fund necessary to be raised to meet the conditions laid down in the will of our late Secretary, the distinguished Dr. William H. Wahl, as precedent to the receipt by the Institute of his estate of approximately $90,000. It is gratifying to be able to report that this fund has been completed and that the estate of Dr. Wahl has been transferred to the Institute as, and under the conditions, desired by him. It is particularly gratifying to be able to report that all the money received for the Wahl Fund came from members of The Franklin Institute.

The Wahl estate and subscriptions, with the Shippen bequest (referred to in the Annual Report of last year, but received during the year covered by this report) increase the productive funds of the Institute approximately $300,000 and practically double the Institute's endowment fund as it stood a year ago.

The regular income of the Institute, for the first time in its history, so far as known to us, is sufficient for carrying on the work immediately in hand. It offers no margin applicable to desirable extensions in the scope of our work. Such extensions will not be undertaken until the assured income of the Institute is sufficiently increased to justify them.

The Institute's new Building Fund has been increased during the year through the sale of the Sixteenth and Arch Streets properties by $55,000. The Institute owned these properties through the generosity of one of its members. They stood on the books of the Institute as valued at $82,000. The Board of Viewers, apportioning the Parkway damages, awarded to the Institute for the properties (and for interest from the date of condemnation) $137,329.50, or approximately $55,000 more than the properties cost the Institute. The Institute's Building Fund now amounts to about $225,000. There is now in the hands of the Board of City Trusts the so-called John Scott Fund, which must ultimately come to the Institute, and which is applicable to the Building Fund, and amounts to approximately $40,000. This makes the total amount now in sight, or ultimately available to the Institute, about $265,000. This is in addition to the very valuable building site located at Nineteenth and Race Streets, on Logan Square. Your Board of Managers believe it will not be wise to proceed with the erection of a building until the present Building Fund of $265,000 has been about doubled, and the normal income of the Institute has been sufficiently increased to justify the undertaking of the coincidentally added obligations.

Your Board of Managers believe that the work the Institute is doing, and which is widely known as good and useful to the citizen, and to the City, State and Nation, will ultimately attract the funds necessary to the erection and endowment of a building better located and more nearly adequate to the accomplishment of the Institute's purposes.

The figures that I have given above are set out in detail and with more exactness in the reports of the Finance Committee, Mr. Forstall, Chairman, and of the Endowment Committee, Mr. Howson, Chairman.

At this writing the Institute owes no money other than current accounts. The "Bills Payable," now (January, 1917) among our liabilities, are debts of one department of the Institute to another.

Your Board, in this general report, cannot do more than briefly comment upon the reports of the several committees which will appear in the 1917 edition of the Year Book.

The report of the Library Committee, Mr. Morgan, Chairman, clearly indicates the importance of a new building for the Institute. It emphasizes what must be known to every member of the Institute who visits our library, the utter inadequacy of our stack and cases. We are compelled to put books wherever there is room for them in the building without reference to their protection or to the convenience of the user. There is no doubt that the library would be greatly more valuable to the citizens of Philadelphia if housed in rooms of adequate size and permitting a more intelligent arrangement.

The report of the Committee on Museums, Mr. Outerbridge, Chairman, is a record of valuable additions of interesting models, etc., contributed to the Museum during the past year.

The report of the Committee on Meetings, Mr. Rogers, Chairman, contains a list of the papers presented at the stated meetings of the Institute, with interesting comments on the May meeting, at which the Franklin Medal was presented to Professor Theodore William Richards and to Dr. John J. Carty, and the Elliott Cresson Medal to Mr. Theodore N. Vail, President, for the American Telephone and Telegraph Company. Addresses were made by Dr. Carty and Mr. Vail. An address by Professor Richards, who was too ill at the time to attend the meeting, was read by Dr. Hoadley. Following the addresses the American Telephone and Telegraph Company gave an interesting demonstration of transcontinental and wireless telephony for the benefit of the Institute's members and guests. This was the first exhibition of the wireless telephony given in our City.

The report of the Committee on Instruction, Mr. Paul, Chairman, gives convincing evidence of the continued good work of the School. The Committee on Instruction was compelled to accept the resignation of Professor William H. Thorne, for thirty years Director of the School. Mr. Simeon van T. Jester, Assistant Director of our School, and otherwise experienced in educational work, was elected Director as successor to Professor Thorne. The membership of the School during the year was about fifteen per cent. greater than during the previous year.

The report of the Committee on Elections and Resignations of Members, Mr. Gibbs, Chairman, indicates that the Institute has not grown materially in numbers during the past year—the membership list having increased but thirty-one in the twelve months. The Institute, during the year, has not made any special effort to increase its membership.

The report of the Committee on Publications, Mr. Levy, Chairman, is of the usual encouraging character. One matter in connection with the Committee's work during the year, to which your Board of Managers wish to call attention, is the mechanical make-up and appearance of the JOURNAL. The character of the paper has been improved, the margins have been increased, the JOURNAL is now sewed instead of stapled as heretofore. These improvements add greatly to the comfort and pleasure of the user of the JOURNAL, as well as to the JOURNAL's general appearance and permanent character.

The report of the Committee on Sectional Arrangements, Mr. Day, Chairman, is practically a report of the meetings held during the last year. The attendance many times taxed the capacity of the hall. The meetings held under the auspices of this Committee last year were particularly successful and valuable.

The report of the Committee on Science and the Arts, Mr. Bonine, Chairman, evidences the continuation of the good work of the Committee, and further, that the value and importance of the Committee's work is becoming more widely recognized year by year. One evidence of this is the number of applications for investigation received: in 1914, nine; 1915, sixteen; and 1916, twenty-five.

As time passes the Institute occupies a larger space in the horizon of Philadelphia's affairs and of its general activities. This is manifested in the greater extent to which the public journals take notice of its proceedings, and in the size and character of its audiences. It is a condition largely created by the eminence of the men who come to the Institute to tell their message in the domain of science and the arts. To these eminent men the Institute offers an immediate audience often as large as its audience room will accommodate, and, through its JOURNAL, a multitude of readers whose habitat is conterminous with the world of scientific thought.

Members of The Franklin Institute, we, your Board of Managers, believe ourselves justified in reporting to you that the work of your Institute continues to be good. But we can only satisfy our sense of duty, and justify our succession, to those far-sighted and devoted men—the founders of the Institute—by relating this actual "good" to an ideal "better" and devoting ourselves to its accomplishment. To this ambition we each year dedicate ourselves anew; and at this, our ninety-fourth Annual Meeting, and on this, the two-hundred and eleventh birthday of our great exemplar, Benjamin Franklin, we again bespeak your encouragement and coöperation.

Respectfully submitted,
The Board of Managers,
WALTON CLARK,
President.

PHILADELPHIA, January 17, 1917.

COMMITTEE ON SCIENCE AND THE ARTS.

(*Abstract of the Stated Meeting held Wednesday, January 3, 1917.*)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, January 3, 1917.

MR. C. E. BONINE *in the Chair.*

The following reports were presented for first reading:

No. 2669.—The Telescribe. Advisory.

No. 2678.—McKeen Motor Car. Advisory.

The following reports were presented for final action:

No. 2677.—"Midget" Marvel Flour Mill.

Alfred Rishworth Tattersall recommended to the City of Philadelphia for the John Scott Legacy Medal and Premium.

No. 2682.—Hooven Automatic Typewriter

Edward Longstreth Medal of Merit to the Hooven, Owens, Rentschler Company. Thomas A. McCall and John H. Pillings recommended to the City of Philadelphia for John Scott Legacy Medals and Premiums.

No. 2684.—The Schoop Metal Spraying Process.

Max Ulrich Schoop recommended to the City of Philadelphia for the John Scott Legacy Medal and Premium.

R. B. OWENS,
Secretary.

SECTIONS.

Section of Physics and Chemistry.—A Stated meeting of the Section was held in the Hall of the Institute on Thursday, January 4, 1917, at 8 o'clock P.M., with Dr. Gellert Alleman in the chair. The minutes of the previous meeting were approved as read.

R. A. Millikan, Ph.D., Sc.D., Professor of Physics in the University of Chicago, delivered a lecture on "Radiations from Atoms and Electrons." The present status of experiment and theory with respect to the nature of the disturbance of the ether, which constitutes a light wave, was described. The evidence for the discontinuous emission of radiant energy by atoms and electrons, and the bearing of this evidence upon atomic structure were discussed. The lecture was illustrated with lantern slides.

The communication was discussed by Drs. Barnes, Goodspeed, Carty, Ives, and others. A vote of thanks was extended to Dr. Millikan, and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

Section of Physics and Chemistry.—A stated meeting of the Section was held in the Hall of the Institute on Thursday, January 11, 1917, at 8 o'clock P.M., with Dr. Gellert Alleman in the chair. The minutes of the previous meeting were read and approved.

Wilder D. Bancroft, Ph.D., Professor of Physical Chemistry in Cornell University, delivered a lecture on "Colloids." The nature of colloids and their relation to both pure and applied chemistry and to the biological sciences were discussed at length. The lecture was illustrated with experiments. The paper was discussed by Drs. Hering, Creighton, Taggart, Hepburn, and others. A vote of thanks was tendered to Dr. Bancroft, and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

MEMBERSHIP NOTES.

(*Stated Meeting, Board of Managers, January 10, 1917.*)

ELECTIONS TO MEMBERSHIP.

RESIDENT.

MR. WALTER S. CROWELL, chemical engineer, 121 East Gorgas Lane, Mt. Airy, Philadelphia, Pa.

MR. JOHN D. GILL, chemical engineer, 3144 Passyunk Avenue, Philadelphia, Pa.

MR. HAROLD GOODWIN, JR., electrical engineer, 1000 Chestnut Street, Philadelphia, Pa.

MR. W. O. GRIFFITH, Stenton and Evergreen Avenues, Chestnut Hill, Philadelphia, Pa.

MR. RICHARD C. SELLERS, civil engineer, Swarthmore, Pa.

NON-RESIDENT.

DR. HAMILTON BRADSHAW, chemist, Experimental Station, Henry Clay, Delaware.

MR. VICTOR W. ZILEN, mechanical engineer, 265 Garside Street, Newark, New Jersey.

ASSOCIATE.

MR. PHILIP WERNER AMRAM, student, 3924 Spruce Street, Philadelphia, Pa.

CHANGES OF ADDRESS.

MR. HAROLD V. COES, 5127 Pulaski Ave., Germantown, Philadelphia, Pa.

MR. LEONARD KEBLER, Avon Road, Bronxville, New York.

MR. MARSHALL MILLER, P. O. Box 232, Orono, Maine.

MR. OSCAR L. SCHEHL, 1631 Girard Avenue, Philadelphia, Pa.

DR. FIN SPARRE, care of E. I. du Pont de Nemours & Company, Room 450, du Pont Building, Wilmington, Delaware.

MR. LOUIS TAWS, 6654 Lincoln Drive, Germantown, Philadelphia, Pa.

MR. CHARLES H. WERNER, 61 Broadway, New York City, N. Y.

MR. J. S. WHITNEY, 1509 Arch Street, Philadelphia, Pa.

DR. ORVILLE WRIGHT, 15 North Broadway, Dayton, Ohio.

MR. CHARLES W. YOUNG, New Stock Exchange Building, 1411 Walnut Street, Philadelphia, Pa.

NECROLOGY.

Lt.-Col. Theodore Turrettini.—On the 7th of October, 1916, there died at his home in Geneva, Switzerland, in his seventy-second year, Mr. Theodore Turrettini, soldier, statesman, engineer and man of affairs. He was an honorary member of the Franklin Institute, having been elected September 17, 1890.

He was Colonel of Artillery in the Swiss Army and had been President of the City of Geneva; but was perhaps most widely known among Engineers for his work in connection with the development of the water power of the Rhone and the control of Lake Leman. He was a member of the Administrative Council which represented all of the interests involved in the selection of the best plan and its execution. As President of the Technical Commission, he conducted the necessary studies, made recommendations to the Council and supervised construction.

He was noted in his own country for his ability and versatility; but is perhaps chiefly interesting to us for his service as a member of the International Niagara Commission.

It will be remembered that this Commission was charged with the duty of selecting the plans for the generation of power by water and its transmission to a distance not less than to Buffalo, by the most economical method, without restriction as to the transmitting medium.

At that time a good deal had been done in rope transmission, and by the use of compressed air; but very little had been accomplished in the long distance transmission of electricity for power purposes. The projectors of the Niagara enterprise, realizing the vital importance of a wise selection, placed in the hands of the International Commission of Engineers and Scientists the duty of selecting the best plan of those submitted by twenty carefully chosen engineers, designers and manufacturers who were invited to enter the competition.

The Commissioners were authorized to spend $22,000 in prizes for such of the plans as they considered favorably. The members of the Commission were selected with great care to obtain those best qualified; and to give the body a truly international character they were chosen from various countries.

Colonel Turrettini's reputation as a hydraulic Engineer and his recent experience in connection with the Rhone works, fitted him in a peculiar degree for this new task, and he was selected to represent Switzerland which probably then stood in the lead in scientific design and application of turbine water wheels.

The other members were Prof. E. Mascart of the College of France, Dr. Coleman Sellers, former President of the Franklin Institute, Lord Kelvin (then Sir Wm. Thomson), Chairman, and Prof. Wm. Cawthorne Unwin, Dean of the Central Institute of the Guilds of the City of London, who acted as Secretary.

The Commission sat in London in 1891 and made a thorough study of the propositions submitted. The result was the adoption of that offered by Messrs. Faesch & Piccard of Switzerland and the definite decision to employ an alternating current. This latter conclusion was not reached easily, the direct current, earnestly advocated by Sir Wm. Thomson, was fairly well understood; but the alternating current was apparently regarded as still in the experimental stage. Dr. Sellers stood out for the alternating current and his view was adopted. Lord Kelvin, visting Niagara Falls after the completion of the first power house, frankly admitted that the selection of the alternating current had been a wise choice.

Those of us who had the pleasure of meeting Colonel Turrettini when he visited the United States, still retain a vivid recollection of his handsome face, his soldierly bearing and his courteous manner.

C. S., JR.

Mr. Otto Charles Wolf was born in Philadelphia on November 11, 1856, and died at Overbrook, Pa., on December 2, 1916.

He entered the University of Pennsylvania in 1872 and soon after his graduation began his professional career as architect and engineer.

Mr. Wolf was a member of a number of engineering societies; he was vice president of the Northwestern National Bank and a trustee of the German Hospital.

He became a member of The Franklin Institute on January 5, 1883, served on its Committee on Science and the Arts in 1891 and in 1897 and on its Board of Managers from 1897 to 1913.

Mr. E. P. Borden, 421 Chestnut Street, Philadelphia, Pa.
Mrs. C. C. Febiger, 3421 Powelton Avenue, Philadelphia, Pa.
Mr. Isaac L. Rice, President, Electric Boat Company, 11 Pine Street, New York City, N. Y.

LIBRARY NOTES.

PURCHASES.

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ERRATA.

The Partition of the Load in Riveted Joints, by Cyril Batho, M.Sc., B.Eng.

November, 1916, issue of the JOURNAL, vol. 182, p. 553.

Table I, page 564, should appear on page 553; Table III, page 569, should appear on page 574 at end of first paragraph.

The last term of the first equation on age 564 should read:

$$k\left[X_1^2 + X_2^2 + \cdots\cdots + (F - \Sigma X)^2 \right]$$

Page 577 referred to in column 3, Table VI, page 581, should read 584.

Line 26, page 582, should read:

Square inch of nominal rivet section in A and of only 5000.

The equation on page 592 which appears as follows:

$$K = \frac{a\,F}{10^{-4}\,A}$$

should read:

$$K = \frac{a\,F}{10^{4}\,A}$$

The letter *a* in the first equation, page 594, should read q.

$$W_s = \Sigma\,\frac{q^2}{2G}\cdot dV,$$

Electrolytic Dissociation in Non-Aqueous Solutions, by Henry Jermain Maude Creighton.

December, 1916, issue of the JOURNAL, vol. 182, page 745. First line, page 757, should read:

The Dissociating Power and the Degree of Association of

PUBLICATIONS RECEIVED.

Bridge Engineering, by J. A. L. Waddell. First edition, 2 volumes, illustrations, plates, tables, portrait, 8vo. New York, John Wiley & Sons, 1916. Price, $10.

Cosmical Evolution, Critical and Constructive, by Evan McLennan. Second Edition. 490 pages, 12mo. Corvallis, Oregon, author, 1916. Price, $2.50.

University of Kansas, Bulletin, Engineering Bulletin No. 8: The Measurement of Electrical Energy, Electricity Meters, Rates for Electrical Energy, by Geo. C. Shaad and C. A. Johnson. 93 pages, illustrations, plates, 8vo. Lawrence, Kansas, University, 1916.

University of Illinois Bulletin: Subsidence Resulting from Mining, by L. E. Young and H. H. Stoek. Illinois coal mining investigations coöperative agreement. Bulletin No. 91: Engineering Experiment Station. Urbana, Ill., University, 1916.

Iowa State College of Agriculture and Mechanic Arts. Official Bulletin. Volume xv, No. 9: Sewage Disposal for Village and Rural Homes, by C. S. Nichols, Bulletin 41: Engineering Experiment Station. 31 pages, illustrations, map, 8vo.; No. 10: A Study of Oil Engines in Iowa Power Plants, by H. W. Wagner, Bulletin 42: Engineering Experiment Station. 159 pages, illustrations, 8vo.; No. 15: Practical Handling of Iowa Clays, by Homer F. Staley, Milton F. Beecher, Bulletin 43: Engineering Experiment Station. 48 pages, illustrations, 8vo. Ames, Iowa, College 1916.

Canada Department of Mines, Mines Branch: A General Survey of the Mineral Production of Canada During the Calendar Year 1915, John McLeish, B.A. 45 pages, 8vo. Report on the Production of Spelter in Canada 1916, by Alfred W. G. Wilson, Ph.D. 60 pages, 8vo. Ottawa, Government Printing Bureau, 1916.

U. S. Bureau of Mines. Bulletin 109: Operating Details of Gas Producers, by R. H. Fernald, 74 pages, 8vo. Bulletin 122. The Principles and Practice of Sampling Metallic Metallurgical Materials, with Special Reference to the Sampling of Copper Bullion, by Edward Keller. 102 pages, illustrations, plates, 8vo. Bulletin 125: Petroleum Technology 34, The Analytical Distillation of Petroleum, by W. F. Rittman and E. W. Dean. 79 pages, illustrations, 8vo. Monthly Statement of Coal-mine Fatalities in the United States, October, 1916. List of Permissible Explosives, Lamps, and Motors Tested Prior to November 30, 1916. Compiled by Albert H. Fay. 32 pages, 8vo. Miners' Circular 23, Elementary First-aid for the Miner, by W. A. Lynatt and D. Harrington. 22 pages, illustrations, 8vo. Technical Paper 163, Petroleum Technology 38, Physical and Chemical Properties of Gasolines Sold Throughout the United States During the Calendar Year 1915, by W. F. Rittman, W. A. Jacobs and E. W. Dean. 45 pages, tables, 8vo. Washington, Government Printing Office, 1916.

U. S. Department of Agriculture. Bulletin 388: Public Road Mileage and Revenues in the New England States, 1914. A compilation showing mileage of improved and unimproved roads, sources and amounts of road revenues, bonds issued and outstanding, and a description of the systems of road administration, fiscal management, and other factors affecting road improvement in each state. 74 pages, 8vo. Washington, Government Printing Office, 1917. Price, ten cents.

Steam Motor Vehicles. A. DOBLE. (*Society of Automobile Engineers Bulletin,* vol. xi, No. 2, November, 1916.)—Ten years ago steam cars, while not in number in use comparable with gas cars, were produced on a quantity basis. The highly developed White steamer of that day was universally admired and a keen competitor of its gas-driven rival. Despite its excellent record, cars manufactured under that name are now all equipped with gas engines. The Stanley steam car still survives, and has been manufactured without cessation since 1898.

The evolution of this car has been gradual and conservative, and it has enjoyed a well merited reputation for service at low cost. A fire-tube boiler and locomotive-type engine have been used from the first. Improvements have been added only when there was a well recognized demand. Thus have been added those necessities of modern motor cars, such as electric lights, stream-line bodies and one-man top. A condenser was adapted to the car in 1914, and as a result about 200 miles can be covered in one filling of the boiler. Kerosene is now used in the main burner (with gasoline for starting and for the pilot), and the mileage per gallon is high. The fusible plug has been abandoned in favor of a thermostat for shutting off the fuel in case the supply of water runs short.

A large number of more or less ineffectual attempts have been made to produce a satisfactory steam-car by persons ill-informed on the actual requirements and apparently lacking in the necessary understanding of automobile-production conditions. With the introduction of the long-stroke high-speed engine in Europe, the steam car rapidly fell behind in the march of progress. It should not be inferred that motor vehicle makers erred in selecting the gasoline engine. The market demanded cars in great number, and the makers chose the only practical power plant available. No one wanted a vehicle that emptied a horse trough every 20 miles. Few drivers were equal to the task of properly feeding the boiler or of devoting from a quarter of an hour to an hour and a half to starting.

With recently perfected equipment steam cars can run 1000 to 1500 miles on one filling (24 gallons) of the water tank. Boiler troubles have been minimized and it has been finally discovered that kerosene can be ignited by the electric spark with certainty and regularity, thus eliminating the former inconvenience of "firing-up." A water-tube type boiler and a single-expansion uniflow engine are noteworthy features of the new equipment.

CURRENT TOPICS.

Rubber Sponge. A. H. King. (*Metallurgical and Chemical Engineering,* vol. xv, No. 12, December 15, 1916.)—Rubber sponges have been in use for quite a number of years, but until recently no one has attempted to utilize their rather peculiar properties in any other way than as a substitute for the natural sponge. Among the many methods of preparation, the time-honored practice has been to mix with the batch some material such as ammonium carbonate, which at the temperature of vulcanization gives off a considerable volume of gas, and thus causes porosity.

Because of its cellular structure, rubber sponge has several very peculiar properties; for example, it has the lowest apparent specific gravity of all solid bodies, its value being about 0.05. In spite of its cellular structure it is water-tight and very nearly gas-tight. While it is honeycombed with minute cells, each cell is an individual unit and the rate of diffusion of gases through it is comparatively low. Perhaps one of the most important uses to which it has been applied is in the preparation of life-preservers. It will not water-log, is light, conforms easily to the lines of the body, and is not ruined by a pin-prick. A life-raft made with rubber sponge is as nearly proof against careless handling as one can be. All sorts of floating devices, such as buoys, markers, etc., may be improved by its use. A promising application is as a tire filler for automobiles. The most satisfactory tire filler available to date is air. It is now proposed to use rubber sponge molded to fit the inside of the tire casing, and in this manner produce a puncture-proof tire. The car still rides on air, but the air is confined in innumerable little sacs.

Hard rubber sponge is also available. It is prepared from soft rubber sponge by further vulcanization, and has many applications as heat insulating material, and, where lightness is desirable, to many minor structural parts. It has in fact considerable strength, and has been proposed as a material for the framework of aeroplanes. It has also been recommended as a material for constructing automobile bodies.

New Electrical Device for Detecting Gas. C. M. Means. (*Coal Age,* vol. 10, No. 25, December 16, 1916.)—The portable electric miner's lamp whose use is constantly increasing, will not detect the presence of gas, and it is the present practice to use the ordinary flame safety lamp for that purpose. The device under consideration is intended to be used in testing for gas in connection with electric lamps. It consists essentially of two glowers connected in series and placed in a vertical position side by side. These glowers are inclosed with glass and gauze, the glass being for observation purposes and the gauze to allow free circulation of air or gas and still prevent the communication of flame to the outside. The device is not at all likely to ignite gas even if the glass is broken, as the temperature of the glowers cannot be raised to the ignition point of a mixture that can be ignited. This indicates the possibility of making a perfect device that will not ignite methane under any circumstances. It can be placed close to the roof where gas is most likely to be found, requires no adjustment, and should be equally reliable under all conditions of air.

The presence of gas is determined by comparing the relative brilliancy of the two glowers. In case gas is encountered one of the glowers brightens and the other dims. Exact percentage of gas cannot be ascertained but can be approximated with a little practice. The principle employed is the use of one glower that will give catalytic action when in the presence of gas and another arranged in the same plane which will not. The glower possessing catalytic properties heated to a proper temperature by some external means will increase in temperature when brought into contact with methane. The glower which does not possess this property is raised to the same initial temperature, but dims when brought into contact with gas, due to the increased resistance of the other glower. So long as the two are in air, they remain at the same temperature and glow alike. Both glowers are made of the same material, but they have undergone a treatment that renders one highly catalytic and the other non-catalytic. By allowing the glowers to be energized for a period of time in mixtures containing high percentages of gas, they may be volatilized. By high percentages is meant 20 per cent. methane or more. However, if properly operated there is no occasion for trouble, even at these high percentages, since if the temperature is high, the limit of explosibility has passed.

Modern Transformer Development. M. M. SAMUELS. (*Electrical World,* vol. 68, No. 21, November 18, 1916.)—Probably the most remarkable progress in electrical construction is typified by the evolution from the first transformer to present-day standardized apparatus rated as high as 140,000 volts, this great stride taking place in the short period of only thirty years. Transformers are now being built for very high voltages and ratings for both single- and three-phase circuits. To give an approximate idea of the enormous size of modern transformers for average installations, it may be pointed out that the 10,000-kw., three-phase, 6,600-66,000-110,000-volt units which have been installed by the Tennessee Power Company in its various power houses on the Ocaee River, occupying floor space of approximately 20 by 8 feet, are about 19 feet high and weigh approximately 200,000 pounds. Since, as is evident, such apparatus could not be shipped assembled, the tanks had to be riveted together in the field. This, of course, requires special care since the facilities of the modern transformer factory are not available in construction camps, the latter being generally located at a considerable distance from any industrial centre.

Indoor-type transformer tanks are built mostly of corrugated steel and are mounted on cast-iron bases. Steel bases are being used more extensively than they formerly were, however, on account of the fact that modern welding methods permit attaching them to the tanks very easily. Since indoor transformers of large rating are always water-cooled, no special radiators are required, the tank surface in addition to convection currents in the water being sufficient to carry away the heat generated. In hydro-electric power houses where great quantities of water are available at little cost, the cooling water is usually taken from the intake, circulated through the transformers under the force of gravity, and discharged into the tail race, so that no elaborate water piping is required. At sub-stations, however, where city water often has to be used or when water has to be pumped at great expense, a saving can usually be realized by installing cooling facilities and recirculating the water through the transformer. Cooling towers have been used to great advantage for this purpose, but recently cooling ponds with spray nozzles are being preferred by most engineers. In steam stations it is sometimes an advantage to pass the transformer water through the water heaters, thus utilizing part of the energy lost through radiation from the transformers. Piping complications, however, sometimes arise when this arrangement is adopted which interfere with the high-tension wiring.

Reverting to transformer construction, it may be pointed out that bushing troubles have been practically eliminated and tank construction so improved that leakage now occurs very rarely. High voltage testing transformers are available at the present time in all test rooms, the highest test pressure used for practical purposes being about 750,000 volts. By installing the transformer and high tension switching in inclosures and interlocking the compartment door with the low-tension oil switch of the transformer, the operation of these high-tension test sets has been made practically hazardless.

Homogeneity of Expansion of Invar. C. E. GUILLAUME. (*Comptes Rendus,* vol. 165, No. 26, p. 966. December 26, 1916.)—The minimum value of the temperature coefficient of the ferro-nickels is very marked with respect to the ratio of their components, and variations from this ratio in invar, properly so-called, is accompanied by a decided increase in the value of the coefficient. The addition of other metals or metalloids, of which several (Mn, C, Si) are necessary to insure workable alloys, raise the minimum value itself, and as the exact composition of a commercial cast can never be exactly controlled, the expansion coefficient varies in an appreciable degree from one cast to another. It is therefore essential, in applications to precision apparatus, to make separate determinations upon samples drawn from each cast.

It may properly be asked if such a determination upon a given sample is fairly representative of the entire cast, since the rate of expansion is governed not alone by the composition but as well, in a great measure, by the treatment to which the piece has been subjected. This is a most important question in many applications, particularly in geodetic base-line bars and wire measures, and in pendulums. The examination of bars 4 meters in length is tedious and costly and the determination is made upon a bar 1 meter in length from the same ingot and subjected to the same treatment. Pendulums are standardized from a representative sample of a given heat. Wires are drawn from selected material and calibrated by the examination of several samples. An additional complication occurs in wires. In fact, when pieces of considerable volume are used, local variations of the coefficient of expansion average together into a uniform mean value, while in pieces of small dimensions, marked irregularities occur. For instance, in watch hair-springs, whose thickness is of the order of one one-hundredth of a millimeter, the effects of segregation are very marked. Despite the multiplicity of factors which affect the expansion of invar, the properties of a sample are a satisfactory criterion, even for precise measuring apparatus, of the part represented.

Origin of the Canning Industry. A. W. BITTING AND K. G. BITTING. (*Canning and How to Use Canned Foods,* National Canners' Association, 1916.)—Canning is the art of preserving a food through sterilization by heat, and maintaining it in that condition in a hermetically sealed container. In its highest development it is an attempt to maintain the food in as nearly the natural condition as possible, or in the condition in which it is usually consumed. Previous to the introduction of this method resort had to be made to pickling either in salt or vinegar, to drying to smoking, and to preserving in sugar. Each of these methods was applicable to certain products, but was productive of change in character, and was attended by so much spoilage in holding that other methods that would overcome these objections would naturally meet with success. Canning leaves much to be desired, but is a vast improvement over other methods, besides it is applicable to so many products which cannot be conserved in any other manner, and withal is so simple that it can be used in the home as well as in the factory.

The art of canning had its origin near the end of the eighteenth century when, among the military measures enacted by the French Government, a bounty of 12,000 francs was offered for an improved method of preserving foods. Nicholas Appert, an expert confectioner, brewer, distiller and chef, was among those who began experimenting; he worked from 1795 until 1804 before he attained his first success which consisted in heating the product and then hermetically sealing the container. He continued his efforts, using many different substances, and so perfected the process that in 1810 he published the results. He was awarded the prize and almost universally honored as the discoverer of the art of canning. Appert did his work so thoroughly and the method was so simple that others began using it as early as 1815, and it was put into commercial practice in 1820. According to his account, he packed his products in glass bottles, added sufficient water to cover, inserted the corks, and then placed them in the water bath. They were heated very gradually for varying lengths of time, depending upon the character of the food. He obtained a temperature of 190° to 200° F. in the center of the bottles, the maximum being 212° F. He used glass exclusively, and achieved results which are difficult to surpass with all our modern equipment.

Appert did not know why foods kept when treated according to his method, and ascribed it to the exclusion of outside air after applying sufficient heat to the food. Science had not progressed sufficiently to determine the real cause for keeping, and, naturally, conclusions were drawn which seemed to coincide with what appeared to be the controlling factors in practice. The French government appointed Gay Lussac to investigate the cause for keeping. He reported that spoiling is a series of oxidation changes, and that by the exclusion of the outside air these changes were prevented in bottled or canned foods. It is now known that all foods, water, air and the containers are bearers of bacteria and other micro-organisms, that the effect of heat is to destroy them, and that the hermetic container merely excludes those from without. The honor of discovering most of the fundamental principles involved also belongs to Pasteur, though his work was in reality directed along a different line.

The first application of bacteriology to canning in this country was made by H. L. Russell, of the University of Wisconsin, in 1895. He was followed by Prescott and Underwood, at the Massachusetts Institute of Technology, in 1896. Since that time sufficient work has been done to enable the processing of all lines of food products with comparative safety.

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ON THE ACOUSTIC EFFICIENCY OF FOG SIGNAL MACHINERY.*

BY

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SECTION I. HISTORICAL REVIEW OF FOG-SIGNAL EXPERIMENTS.

THE use of acoustic signals to warn fog-encompassed ships of dangerous localities or of impending collisions probably dates back to the very earliest days of navigation. As the range of the human voice in the open air is very limited, bells, gongs, or trumpets were employed in the earliest times to cover the distance required. With the invention of gunpowder, long-range signals were realized by firing off small cannon or mortars and such methods are, in some localities, still employed to the present day. In the leisurely days of sailing ships, likely to be entirely becalmed in foggy weather, the danger of collisions or of shipwreck was comparatively small. With the introduction of steam navigation and the development of keen competition for freight, the danger occasioned by taking the risk of navigating in foggy weather led to a heavy toll of lives and property through many disastrous shipwrecks. Speaking for the seaboard of Great Britain about the year 1875, Professor Tyndall states that during ten years at this period no less than 273 vessels were reported

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as totally lost in fog or thick weather.[1] He states, furthermore, that the loss was far greater on the American seaboard where fogs are more frequent.

It is not surprising, therefore, that the attention of various governments should have been directed to the study of improvement in the means of transmitting acoustic signals over long distances. Any attempt on my part to give even a partial account of the numerous tests which have been carried out on the subject of fog-signals would occupy the space of several complete lectures. I shall, therefore, be obliged to state very briefly the main results which have been arrived at by various investigators in order to present the outstanding difficulties in transmitting acoustic signals with the economy and certainty desirable in these important aids to navigation—difficulties which have by no means, as yet, been entirely overcome.

In the year 1873 the Trinity House of Great Britain set on foot trials with sound signals, following on a visit of a Committee of Elder Brethren to the United States the preceding year. A special committee was appointed to carry out these tests with the advice and assistance of Professor Tyndall, then scientific adviser to the corporation. An elaborate series of experiments was carried out at South Foreland, near Dover, the results of which formed the subject of a lengthy report. Tyndall's contributions were presented to the Royal Society of London, and his memoir on the subject was published in the Transactions for the year 1874.[2] The subject is dealt with at length in Tyndall's well-known work on "Sound," which has proved an invaluable guide and inspiration to so many workers on the subject of acoustics. In these tests the audibility of the signals was estimated entirely by ear. This is, of course, the most simple and practical method of carrying out the test, inasmuch as the experiment is carried out under the same conditions as when the signals are heard by the navigator himself. As a method of comparing the relative merits of different types of fog-signal installations, this procedure leaves little to be desired, and information derived in this simple manner has been invaluable in the progress of fog-signal engineering. The results of this investigation are admirably summed up in a later Trinity House Report for 1901, to which I shall refer later, as follows:

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[1] Tyndall, "Sound," 3rd edition, Chapter vii According to statistics compiled for the seaboard of Newfoundland by Mr. R. White, Inspector of Lighthouses, it appears that between the years 1820 and 1903 no less than 558 wrecks occurred in these waters, a large proportion, it is to be presumed, owing to fog. The positions in which ships have been lost to the year 1909 are shown on a "wreck chart" prepared by Mr. White and published by Messrs. Garland and Co., St. Johns, Newfoundland.

[2] Tyndall, "On the Atmosphere as a Vehicle of Sound," *Phil. Trans.*, vol. 164, 1874, pp. 183–244.

"(1) The passage of sound through the atmosphere is not impeded by fog, or by falling snow, hail or rain;

(2) The most powerful sound-producing instrument then known was the siren as used in the United States;

(3) No sound signal should be relied on for being heard at a greater distance than two or three miles;

(4) Sound shadows may be formed by the intervention of points of land or the interference of the reflected sounds with the direct waves, whereby a signal may be rendered much less effective or quite inaudible in the area of such a sound shadow;

(5) An opposing wind seriously obstructs or diverts the passage of sound waves, while to leeward the sound travels to great distances without any serious interference;

(6) In an optically clear atmosphere the air may be rendered flocculent to sound by the existence of invisible acoustic clouds formed by air currents differently heated or differently saturated with vapor."

Meanwhile many observations and trials of the greatest importance relating to fog-signals were being made in the United States by the light-house engineers of that country. The experiments and reports of General Duane as well as those of Professor Joseph Henry were described and published in the Report of the Light-House Board for 1874.[3] For the most part, the experiences of the British and American experimenters was in general agreement, although the interpretation of many of the remarkable and unexpected phenomena observed formed for some time the subject of controversy between Henry and Tyndall. One of the most interesting features of this report is that, for the first time in the history of the subject, as far as I have been able to gather, an attempt was made by Professor Henry to employ a physical method of *measuring* sound intensity, as that distinguished scientist evidently realized how unsatisfactory the ear was for the purpose. As early as 1867 he compared the action of a steam-siren, at Sandy Hook, with that of a Daboll trumpet, employing for the purpose a stretched membrane covered with sand placed at the small end of a conical tube which concentrated the sound-wave upon the membrane.

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[3] Reproduced in the "Scientific Writings of Joseph Henry," Smithsonian Institution, 1886, vol. i, pp. 370–510.

The results of fog-signal tests carried out in the United States to the year 1894 are published at length in Major Livermore's Report to the Light-House Board for that date.[4] I shall have time to mention only two points of this report which have a bearing on the main theme of my lecture this evening. In these tests, somewhat more elaborate means of measuring sound intensity than had hitherto been employed were devised by the scientific observers, Dr. White and Professor Hazen. In measuring the intensity of a signal, a standard scale of numbers was adopted in which zero denoted the absolute inaudibility of a signal and 100 its full power at a distance of 1000 yards with no intervening objects and under favorable conditions. The number 10 was chosen to denote the least sound of a signal which would be unmistakable supposing the observer to be unaware of the moment when it is to be expected. In order to standardize these estimates a sound-box was constructed of black walnut, 4 × 3 × 2 inches, provided with a sliding cover and completely enclosed with thick felt. The sound was produced by means of a Jew's-harp fastened above a resonance cavity and sounded by an external lever. The sound proved to be so similar to that of a fog-alarm bell as to make the two difficult to distinguish when the intensity of the standard was adjusted to equality with that of the signal by sliding the cover or by removing the box to a suitable distance from the observer. It is evident that in this way a definite, though arbitrary, scale of intensity could be adopted and, if necessary, converted into an absolute scale by a laboratory measurement of intensity and quality. Although this was suggested at the time of the tests referred to, I have been unable to discover any record to indicate that this plan was ultimately carried out.

Another feature of Major Livermore's report to which I should like to refer here is the method there adopted of representing graphically the variation of sound intensity on the course of the observing ship in the neighborhood of the fog-signal. The intensity of the signal according to the scale just described is indicated by the breadth of the line representing the track of the ship on a chart of the locality. In this way the capricious fluctuations of the strength of the signals under various conditions of wind and weather are indicated at a glance. In somewhat modified form I have adopted this method of representing the results of my own observations. (See Charts I, II and III.)

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[4] Livermore, "Report Upon Fog Signal Experiments," Appendix No. v to the Report of the Light-House Board, Washington, 1894.

In the year 1901 an important series of tests was carried out by a special committee of the Trinity House under the scientific direction of Lord Rayleigh and Sir Thomas Matthews, Engineer in Chief.[5] The object of the trials was to discover the relative merits of various new types of fog-signal machinery. The experiments were carried out at St. Catherine's Point, Isle of Wight. Several members of the Committee always participated in estimating the strength of the signals by ear. Numbers on a scale ranging from 1 to 10 were assigned by the observers to represent the values of the sound heard. These were entered on special cards provided for the purpose and in comparing the relative merits of fog-signal apparatus the figures were averaged so that it was possible to say that siren *A* was 50 or 100 per cent. better than *B*. I am unable in the time at my disposal to give more than a passing reference to the most important results of these tests, which have, to a large extent, determined existing practice in Great Britain and Canada since that time. It was decided that in operating compressed air sirens little advantage in range of audibility accrued from raising the pressure above 25 pounds per square inch. For calm weather a low-pitched note (about 180 complete vibrations per second) was considered most suitable; when the wind was opposed to the course of the sound-waves or when the sea was rough and noisy, it was found that a high-pitched note penetrated further than a low-pitched one. The physical significance of these observations was discussed in a paper by Lord Rayleigh, published in the *Philosophical Magazine* for 1903.[6] It may occasion some surprise when I state that while a blast is being sounded from a siren which can be heard about eight miles on a good day, energy is being expended at the rate of about 100 horse-power. While the high note of a Scottish signal tested at St. Catherine's was being sounded, the expenditure of as much as 600 horse-power was required. Lord Rayleigh raised the question as to whether these enormous powers are really utilized for the production of sound, or whether from some cause, possibly avoidable, a large proportion may not be wasted. By means of a simple mathematical calculation relating to the 7-inch disk siren tested at St. Catherine's, Lord Rayleigh concluded that the maximum pressure-change (estimated at 1/180 atmosphere) in the sound-wave produced was but an insignificant fraction of the operating pressure (25 pounds per square inch) and inferred that the conical trumpet acting as a resonating tube played an important part in utilizing the pressure of the compressed air. He also believed that a large proportion of the power applied to existing forms of sirens was not converted into sound, and that there was room for improvement in their construction with a view to reducing the very large demands made.

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[5] "Report of Trinity House Fog Signal Committee on Experiments Conducted at St. Catherine's Point, Isle of Wight, 1901." (Darling and Sons, Ltd., London.)

[6] Rayleigh, "On the Production and Distribution of Sound," *Phil. Mag.*, vol. vi, 1903, pp. 289–305; "Scientific Papers," vol. v, pp. 126–141.

The experience of the French fog-signal engineers is summed up in a work published in 1908 on lighthouses and marine signals by Dr. C. Ribière, the Engineer-in-Chief, who has himself made many notable contributions to the subject.[7] As one would expect of the French scientific attitude of mind, serious and long-continued attempts were made to adapt some of the several known laboratory methods of measuring sound intensity in the hopes of elucidating some of the difficulties which I have just mentioned. Ribière states that attempts were made to record the motion of membranes vibrating under the influence of the signals; to measure the electric current generated by the vibrations of a telephone diaphragm; to record the signals on a phonograph-record, and to measure under a microscope the depth of the impression produced. Optical methods depending on the use of the interferometer to measure the change of refractive index in the atmosphere due to the passage of the sound-waves were also tried, as well as several other methods described in treatises and scientific journals. It was concluded that, while sound-intensity was capable of measurement under laboratory conditions, no means then existing could be employed successfully in engineering practice. For the most part the results of the French experiments agree with those of the British and American engineers except in a few points of technical detail which I shall not touch upon here, except by mentioning that a great deal of insistence is placed upon the desirability of obtaining further knowledge on the subject of the *acoustic efficiency* of fog-signal machinery. For the first time in the history of the subject, as far as I am aware, Ribière definitely suggests that sound-waves generated by a siren probably bear a close relationship to explosive waves whose mode of propagation has long been known to be very different from that represented by the classical theory of ordinary acoustics. Explosive waves have been studied experimentally in great detail by the ordinance department of the French artillery service. It is not surprising, therefore, that the part played by these abnormal phenomena in relation to fog-signal waves should have suggested itself to the French engineers. With this special aspect of the subject I shall deal in connection with my own observations.

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[7] Ribière, C., "Phares et Signaux Maritimes" (Encyclopédie Scientifique, Octave Doin et Fils, Paris, 1908).

SECTION 2. ON THE PRODUCTION OF SOUND BY THE NORTHEY DIAPHONE.

If I have taken up a considerable amount of time in presenting in a very summary fashion the experiments of previous investigators, it must not be inferred that I was familiar with the works of the authorities I have quoted at the time I planned the tests which I have the honor of describing this evening. If I had been in possession of more knowledge of the subject than the theoretical discussions I had read in Rayleigh's " Scientific Papers," which furnished the inspiration to undertake the work, it is hardly probable that I should have ventured into so complex and difficult a field of research. My experience in this connection certainly gives some support to the paradox occasionally heard in research laboratories, that a certain amount of healthy ignorance is the best incentive for undertaking some new line of work. At any rate, it so happened that I had just read Lord Rayleigh's papers on the subject of fog-signals when an opportunity offered itself in the summer of 1912 of accompanying the Director of the McGill Physics Building, Professor Howard T. Barnes, on a cruise to the Straits of Belle Isle, with the object of making a special scientific study of icebergs, which in the North Atlantic constitute a serious menace to the safety of navigation. Accommodation was provided by the Canadian Government on the lighthouse tender "Montcalm" during one of her routine cruises to the Gulf of St. Lawrence. I had in this way very exceptional opportunities of studying the Canadian lighthouse and fog-signal system.

The type of fog-alarm which has found favor in Canadian waters and has been installed in many localities is a modified form of compressed air siren, of extremely elegant mechanical construction, an invention of Mr. J. P. Northey, of Toronto,[8] called by him a "diaphone." The essential feature of this apparatus consists of a hollow piston in which are cut a number of equidistant circular slits or ports whose planes are perpendicular to the axis. This piston fits closely in a cylinder in which are cut corresponding slits. These are alternately opened and closed by the vibratory movement of the piston. These oscillations are produced by means of a special driving head fitted with a valve-system somewhat resembling that of a compressed-air riveter. Air at a pressure of about 25 pounds per square inch is supplied from compressors and storage tanks to a chamber surrounding the exterior stationary cylinder. As the hollow piston vibrates, the intermittent puffs of air generated give rise to intense sound-waves which are propagated to the external atmosphere through a continuation of the outer cylinder in the form of a short conical trumpet tuned to resonance with the pitch of the signal note, about 180 complete vibrations per second. A most important characteristic of the diaphone is the fact that a very considerable variation of operating pressure has very little effect on the pitch of the signal note. This apparatus gives rise to an extremely powerful and well-sustained note whose quality as heard in the distance was, as far as I could judge, that of a very nearly pure tone. At the end of a blast, the slowing down of the piston gives rise to a short and powerful terminal note of diminishing pitch. This "grunt" (as it is designated at sea) is characteristic of the diaphone signal and is of great practical importance in navigation, not only in differentiating the note from that of ship-siren, but in enabling the direction of the signal to be estimated with fair accuracy. This peculiarity was entirely unexpected in the development of the diaphone and is emphasized in modern installations. The purity of the diaphone note, together with the fact that the auxiliary machinery was of such a character as to lend itself extremely well to the control and measurement of air pressure, flow and temperature, made it evident to me that here, *par excellence,* was the type of sound generator suited to a physical study of the mode of propagation of powerful fog-signal waves and of energy losses in the machine itself and in the atmosphere.

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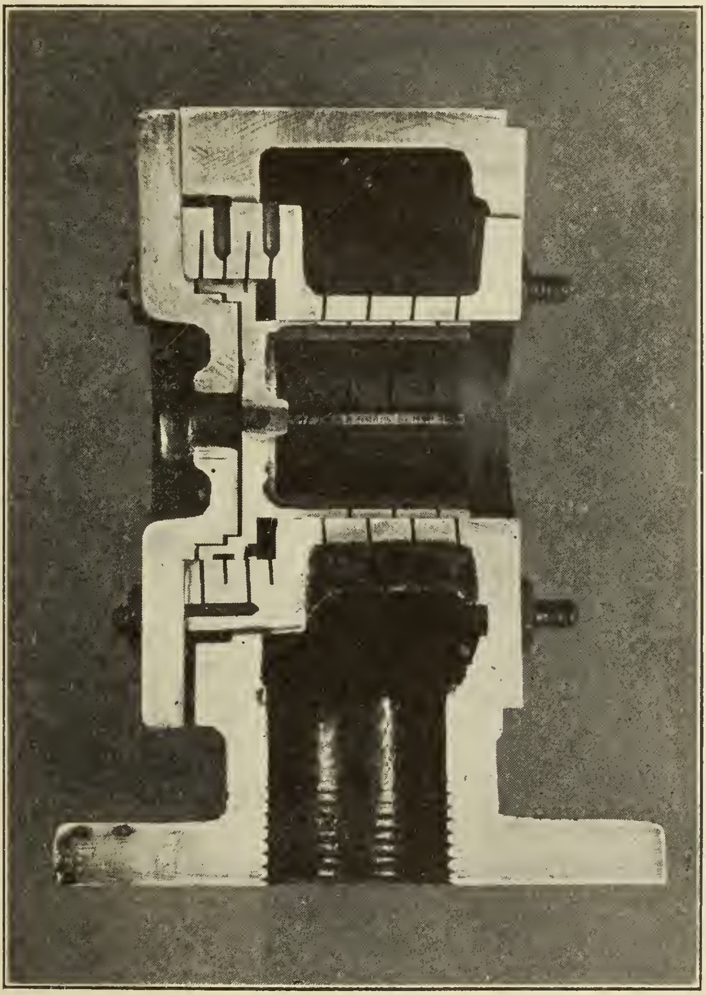
[8] For detailed descriptions of this apparatus, see Northey, J. P., United States Patents, No. 736,428, Aug. 18, 1903; No. 879,190, Feb. 18, 1908; No. 973,960, Oct. 25, 1910; No. 1,016,187, Jan. 30, 1912. The word *diaphone* is compounded of the two Greek words δια = *through* and φωνή = *voice* or *sound*.

FIG. 1.



Small model of Northey diaphone sectioned to show details of construction.

SECTION 3. ON THE NUMERICAL CHARACTERISTICS OF AERIAL SOUND-WAVES IN RELATION TO THE AUDIBILITY OF FOG SIGNALS.

At this point it is necessary for me to interrupt my narrative and present the main lines of theoretical reasoning which led me to plan the researches which I am about to describe. It is a matter of common knowledge that periodical pressure disturbances in the atmosphere may be set up by the vibrations of a bell struck by a hammer, by the rapid oscillations of a stretched string, or by the intermittent escape of puffs of air as in a siren. This pressure disturbance travels outwards in the form of a sound-wave with a velocity of about 1100 feet per second. Let us imagine a superhuman experimenter engaged in studying the effect of sound-waves on a supernaturally sensitive aneroid barometer. He would observe the indicating hand of his instrument fluctuate rhythmically, showing the existence of minute pressure-changes in the atmosphere. If he could follow in detail the motion of the hand of his instrument he would be *analyzing* the sound-wave. A perfectly regular backward and forward motion would correspond to a *pure tone;* an irregular movement, without rhythm, corresponds to a *noise*. Between the two he might observe an infinite variety of periodic types of motion corresponding to what are called *complex tones*. Associated with the pressure fluctuation in a sound-wave is a minute backward and forward motion of each particle of air—referred to as the *displacement*. While all these points are fully dealt with in all text-books on physics, it is somewhat curious that very few answer the question which an engineer would naturally ask, and which is of fundamental importance in fog-signal work—what is the magnitude of these pressure-fluctuations and displacements in a sound of given pitch which is of sufficient intensity, let us say, to be just audible to the normal ear? This question was first answered as long ago as 1870 by Boltzmann and Töpler,[9] and was independently dealt with by Lord Rayleigh in papers published in 1877 and 1894.[10]

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[9] Töpler and Boltzmann, "Uber eine neue optische Methode die Schwingungen tonender Luftsäulen zu analysiren." *Ann. Phys. Chem.*, 1870, pp. 321–352.

[10] Rayleigh, "On the Amplitude of Sound Waves," *Proc. Roy. Soc.*, xxvi, 1877, pp. 248–249. "Scientific Papers," vol. i, p. 328. See also a paper "On the Amplitude of Aerial Waves which are but just Audible," *Phil. Mag.*, 28, 1894, pp. 365–370. "Scientific Papers," vol. iv, pp. 125–129. These experiments are briefly described in Rayleigh's "Theory of Sound," vol. ii, 1896, pp. 434–440.

I have set out in the accompanying table a few of the early estimates of the numerical characteristics of just audible sound-waves, quoted from the papers just referred to.

Numerical Characteristics of Just Audible Sounds.

(Wave-length of yellow light about 6×10^{-6} cm.)

Pitch	Pressure amplitude in atmospheres.	Displacement amplitude in centimetres.	Authority and Remarks.
181	9.2×10^{-8}	$.19 \times 10^{-6}$	Töpler and Boltzmann (1870). Measurement of density fluctuations in organ pipe measured by Jamin refractometer.
256	$6.0 \times 10^{8-}$	0.127×10^{-6}	Rayleigh (1894). Rate of decay of tuning fork fitted with resonator.

The extreme minuteness of the physical effect necessary to influence the ear will no doubt be a surprise to many. The authorities I have just quoted have also drawn attention to a most extraordinary result, not very generally known, and of the highest degree of interest.

Lord Rayleigh estimates that the stream of energy (*i.e.*, the amount of energy in the sound-waves crossing a unit area per second) from an ordinary candle affecting the eye at a distance of 3000 metres (*i.e.*, about 2 miles) is about equal to the stream of energy just audible to the ear. It appears from this that the amounts of energy required to just affect the eye and ear are roughly equal and extraordinarily small. The point should be carefully noted by inventors who propose to substitute auxiliary apparatus to aid the naked ear in detecting fog-signals at sea. The *intensity* of sound is conveniently measured by the flow of energy in the sound-waves crossing unit area in unit time and, in the case of pure tones, is proportional to the square of the displacement- or pressure-amplitude. We are told in text-books of physics that the intensity of sound from a source of disturbance falls off according to the inverse square law, as is the case with radiant energy. In the open air, under conditions met with at sea, the law is not even a rough approximation, as may be seen from an inspection of Charts I, II and III. However, at the time I first became interested in the Northey diaphone, in the summer of 1912, I made a very simple calculation, which we are now in a position to follow. According to the results of Boltzmann and of Lord Rayleigh which I have just mentioned, we know the rate of flow of energy just audible to the unaided ear. If, now, a fog-signal generator is just audible on a favorable day at 10 miles (no very great distance for a modern type of apparatus such as that at Father Point), we are able to calculate the rate at which energy must be supplied at the diaphone, assuming that the inverse-square law holds. Making use of Boltzmann's data (referring to a note of the same pitch) we arrive at the surprising conclusion that the expenditure of energy at the resonator should be a little less than one-third of a horse-power. The diaphone we are considering gives two blasts of 3 seconds each per minute. In order to provide sufficient air, a 10-H.P. gasoline engine operates continuously, compressing air into the storage tanks to be all expended in one-tenth of the interval required to make good the air lost. It follows that, in terms of the engine-power supplied, energy is expended at the rate of 100 H.P. during a blast. We are told in the St. Catherine's report that when the high note of the Scotch siren was being sounded, energy was being spent at the rate of 616 H.P. In order to explain this somewhat extraordinary result we have first of all to settle two questions. First, are fog-signal waves propagated through the free atmosphere on a calm day without loss of energy, and is the inverse-square law true? Secondly, what are the losses of energy in the sound-generator itself, *i.e.*, what proportion of the available horse-power is converted into sound?

I decided, if facilities could be obtained, to undertake a series of tests to obtain some light on these two questions and forthwith took up the matter with Dr. H. T. Barnes, who not only placed the resources of the laboratory at my disposal for the work, but kindly offered to bring the importance of this field of research to the attention of the Canadian Government. As a result, very exceptional facilities for the work were provided by the Department of Marine and Fisheries.

It now became necessary to devise a method of attacking the two problems I have enunciated. Considering these in order, it was evident that the study of atmospheric and propagation losses would require some form of portable sound-measuring apparatus. Such an instrument I thought could be used with comparative accuracy and ease owing to the remarkably smooth note of the Northey diaphone, to which I have already referred. I had not proceeded far in searching through all available papers on the subject of sound-measurement, when I came upon the work of Professor A. G. Webster of Clarke University to whom I addressed a request for a copy of a paper published in the year 1904[11] as a contribution to a volume of scientific papers dedicated to the late Professor Boltzmann. I not only received the paper referred to but an invitation to visit the laboratory of Clarke University and make myself familiar with the most recent developments of sound-measuring apparatus. Of this invitation I readily availed myself in July, 1913, with the result that Professor Webster not only offered to supervise the construction of a "phonometer" specially designed as to pitch and sensitiveness to measure the sound from the diaphone, but placed at my disposal the manuscript of a memoir dealing with the entire theoretical and experimental development of his sound-measuring instruments.

SECTION 4. ON THE MEASUREMENT OF SOUND BY MEANS OF THE WEBSTER PHONOMETER.

The Webster phonometer is, in fact, the practical realization of the ideal, supernatural aneroid barometer which I employed for the purposes of illustration a few moments ago to measure, in imagination, the minute pressure-fluctuations which occur in sound-waves of ordinary loudness. It consists, in brief, of a hollow cylindrical chamber (called a Helmholtz resonator from the first experimenter to study its acoustic properties), one end of which is pierced by a smooth hole communicating freely with the atmosphere. The other end also contains a circular opening over which is cemented a very uniform plate of the best mica obtainable (such as is employed in the construction of phonograph sound-boxes). The resonator is made up of two accurately turned, telescoping cylinders so that its volume may be altered at pleasure. It is a familiar fact that a hollow vessel emits when suitably excited a fundamental (*i.e.*, of lowest pitch possible) note of a certain frequency depending to a slight extent on its shape, but chiefly on its volume. It will also resound to and reinforce a note of the same pitch, a phenomenon referred to as *resonance.* By altering the volume of the resonator of the Webster phonometer it is possible, within certain limits, to "tune" the instrument to any desired frequency. When this adjustment is correctly made, the pressure fluctuations in the interior of the resonator are much reinforced, by an amount which may be exactly calculated. The mica diaphragm at the back of the resonator is thus caused to vibrate, and, if it is possible to measure the amplitude or range of motion of the diaphragm in inches or centimetres, Professor Webster has shown how to calculate in absolute measure the numerical characteristics of the sound-waves in the free atmosphere passing by his instrument. For sounds of ordinary intensity the amplitude of motion of the mica diaphragm is so small that it is necessary to make use of a special optical or interference method to measure it in terms of a wave-length of

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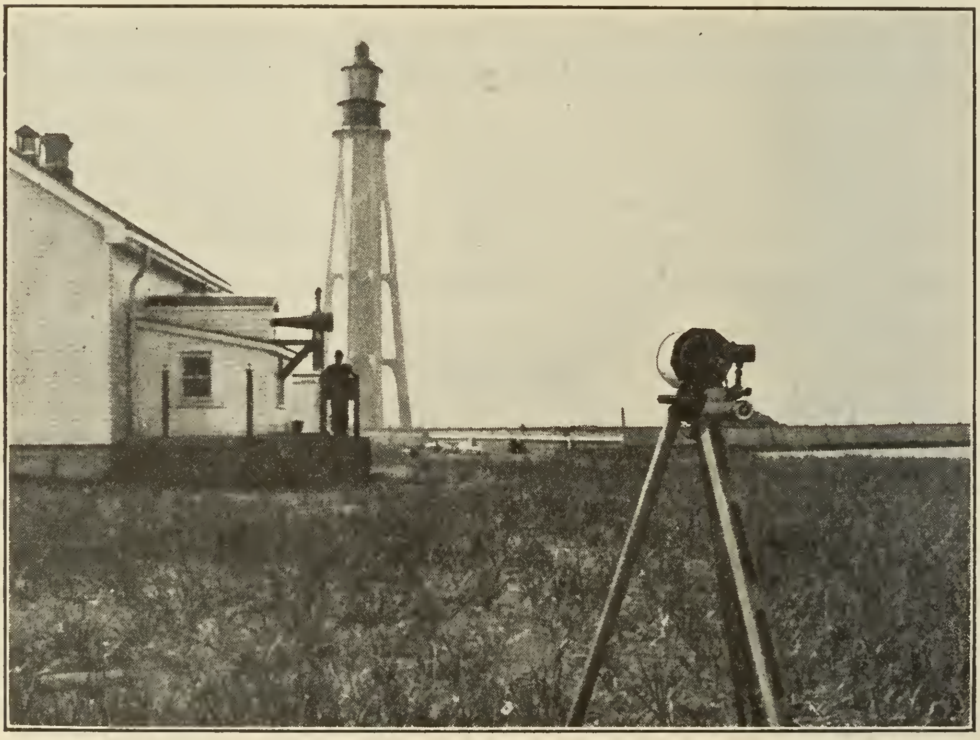
[11] Webster, A. G., "On the Mechanical Efficiency of the Production of Sound," "Boltzmann Memorial Volume," pp. 866–875. (J. A. Barth, Leipzig, 1904.) A short description of the apparatus is given under the title "A Complete Apparatus for the Measurement of Sound," British Association Report, 1910, p. 534.

FIG. 2.



Webster phonometer mounted on a theodolite tripod. Building to the left is the fog-signal station showing the trumpet of the diaphone. Father Point lighthouse in the background.

light. This instrument, which may be called a "standard phonometer," corresponds to the standard electrical measuring instruments which are carefully kept in specially fitted laboratories. For every-day purposes a secondary standard is employed. In order to magnify the motion of the mica disk sufficiently to measure it easily, an ingenious mechanism has been devised by Professor Webster which satisfies conditions of portability and of use under practical conditions. The mica disk carries, firmly clamped at its centre, a sharp steel point. A narrow steel strip, suitably held taut at both extremities in a fork capable of adjustment in two directions at right angles by slow-motion screws, has its centre in contact with the steel pin in such a manner that a slight movement of the point causes it to twist through a small angle. In order to magnify the twist, the familiar galvanometer lamp and scale device is employed in miniature. Cemented to the steel strip is a minute concave mirror. The filament of a small flash-light tungsten lamp is mounted over a microscope eye-piece whose optical axis coincides with that of the phonometer. The straight narrow filament of the tungsten lamp is reflected and concentrated into a distinct image so as to appear sharply defined against a graduated scale in the microscope eye-piece. As soon as the mica disk is set into vibration by sound-waves passing near the resonator, the image of the filament is drawn out into a bright band with sharply defined edges. The width of the band is proportional to the amplitude of the sound-waves as measured by pressure-fluctuation or displacement. This secondary standard may be calibrated in terms of the absolute standard by simultaneous measurements by the two instruments of the note emitted by a standard "phone" (*i.e.*, a sound-generator especially designed to give a pure tone of known characteristics).

The "phone" or standard sound-generator, is merely the phonometer worked backwards: it is easily understood that if the diaphragm of the phonometer is made to oscillate through a known amplitude, it is possible to calculate the numerical characteristics of the spherical sound-waves emitted. By the use of the standard "phone" it is possible, by making use of an ordinary phonometer, to calculate the acoustic output of any sound-generator of the same pitch, such as a violin, a cornet, or even the human voice. For this purpose it is only necessary to have the two sources sounding alternately side by side and adjust the amplitude of motion of the standard source until the same reading is obtained on the phonometer placed at a suitable distance. The amount of mechanical energy required to produce the notes on the musical instruments mentioned is easily measured, so that their *acoustic efficiency,* or ratio of energy input to acoustic output may be determined. Such determinations for ordinary musical instruments were first carried out by this method in 1902 and described in Professor Webster's 1904 paper just referred to. The results are extremely interesting. To quote a few of the determinations only, the acoustic efficiency of the violin comes out to be 0.00052 or about one part in two thousand. That of the cornet is in the neighborhood of 0.0011 or roughly twice as great, while the human voice comes out surprisingly well with an efficiency of 0.0095 or nearly one per cent. These results are summed up by Professor Webster in the graphical statement that it would require ten million cornets all sounded at once to emit a horse-power.

SECTION 5. ON AERIAL SOUND WAVES OF LARGE AMPLITUDE.

The methods just described for measuring the acoustic efficiency of sound-generators of small power depend for their validity on the mathematical theory of sound-waves in which the pressure-amplitude is an extremely small fraction of an atmosphere, at most a few parts in one or ten thousand. It occurred to me when I was planning these tests that it was very probable that the pressure amplitude at the narrowest part of the trumpet of the diaphone could easily amount to a very considerable fraction of an atmosphere, say a hundredth or a tenth. Now, it was pointed out as long ago as 1808 by the French mathematician, Poisson,[12] that in these circumstances the mathematical theory of the propagation of waves of large or finite amplitude was entirely different from that of ordinary sound-waves of very small amplitude. The physical significance of this result was first pointed out in 1848 by Sir George Stokes [13] who showed, without any mathematics at all, that in a plane wave of sound propagated in an ideal elastic fluid (*i.e.*, without viscosity or internal friction, and without thermal conductivity or the property of transferring heat from hot to cold parts of the medium), the parts of the wave where the density is greater will gain continually on those where it is less. Thus, after a certain lapse of time, a discontinuity will occur in a manner somewhat analogous to the way in which a water-wave will break when the accelerations of the water-particles become too great. It is possible to calculate for a plane wave transmitting a given amount of energy how far it will travel before this break will occur. In the case of waves of ordinary intensity and pitch, this distance is many hundreds of times greater than the dimensions of laboratories where such an effect could be observed. It is otherwise, however, when we come to deal with very intense waves, or ordinary waves of very high pitch when the distance referred to may amount to a few metres only. As to what happens when the theoretically calculated discontinuity sets in is still an unsolved problem, especially when dealing with diverging spherical waves. Of course, in reality, the viscosity and thermal conductivity of the air play an important part. This far more difficult problem has been dealt with by Lord Rayleigh [14] in a lengthy and complicated paper published in 1910. The theory is applied to explain the very curious and abnormal laws of air-resistance to projectiles moving with a velocity greater than that of sound.

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[12] Poisson, "Mémoire sur le théorie du son," *Journ. de L'Ecole Polytechnique,* t. vii, 1808, p. 319.

[13] Stokes, "On a Difficulty in the Theory of Sound," *Phil. Mag.,* Nov., 1848; "Mathematical and Physical Papers," vol. ii. p. 51.

If we turn from the attempts of theory to consult the verdict of experiment, which constitutes a court of high appeal to which we must ultimately have recourse, we find that it has long been known that very intense waves, such as those caused by the detonation of explosives, have a velocity distinctly greater than that of ordinary sound. This subject has been studied in great detail by M. Vieille,[15] Engineer-in-Chief of the French Ordnance Bureau (*Poudres et Saltpêtres*). In his memoir published in 1900 he showed that the velocity of the wave generated by the sudden rupture of a thin metal diaphragm under a pressure of 27 atmospheres is nearly double that of ordinary sound, while that of the waves generated by the detonation of modern high explosives attains as high as three times the normal value.

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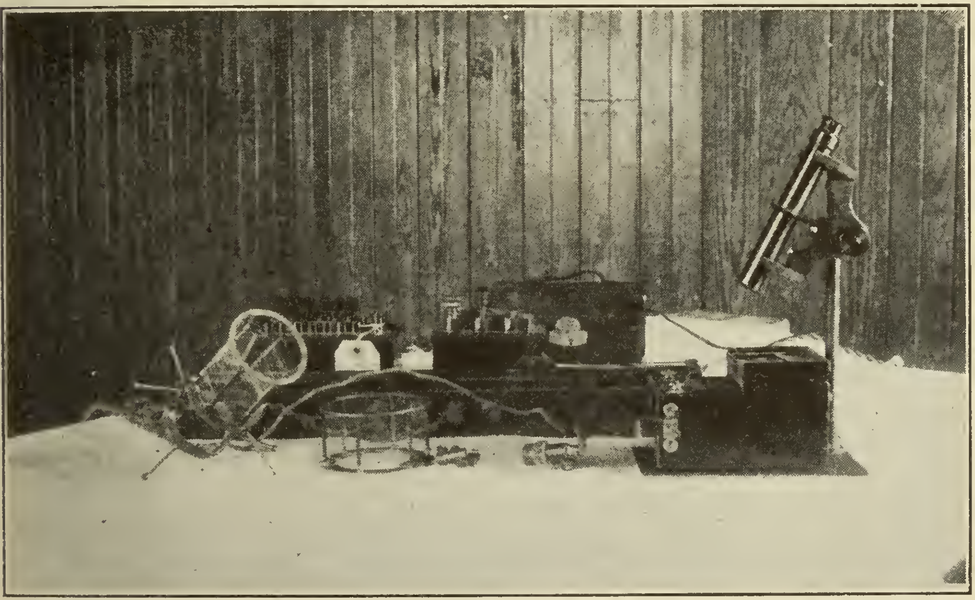
[14] Rayleigh, "Aerial Plane Waves of Finite Amplitude," *Roy. Soc. Proc.*, A, vol. 84, pp. 247–284, 1910; "Scientific Papers," vol. v, pp. 573–619.

[15] Vieille, "Etude sur le rôle des discontinuités dans les phénomenes de propagation," Mémorial des Poudres et Saltpêtres, t. x, pp. 177–260 (Gauthier-Villars, Paris, 1900).

SECTION 6. ON THE THERMODYNAMIC MEASUREMENT OF ACOUSTIC EFFICIENCY.

It is thus evident that we must be prepared to meet with very abnormal conditions in studying the signals emitted by a diaphone, especially close to the oscillating piston, at which point I wished to measure the acoustic output. In this locality the sound-waves probably resemble intermittent explosive waves rather than the normal waves whose characteristics are easily measured by means of the phonometer. It was thus necessary to devise a method of efficiency measurement entirely independent of any acoustic theory, and for the purpose a thermodynamical method, generally applicable to any type of compressed-air machinery, was developed. The principle of the method may be easily understood by reference to a fact familiar to all engineers. It is well known that when a compressed-air drill is being operated at full load, the air which escapes through the exhaust pipe becomes so cold that hoar-frost gathers on its exterior, in spite of the warm surrounding atmosphere. If, however, the air be allowed to escape through the valves into the exhaust pipe without operating the drill, there is no perceptible fall in temperature. It is thus evident that by measuring the temperature difference of the air at the intake and exhaust we should obtain a measure of the rate at which the drill is doing mechanical work, making use of a few simple thermodynamical formulæ. In the application of this idea to measuring the acoustic output of the diaphone, a number of serious experimental difficulties had to be overcome. It was estimated beforehand that the temperature-difference would certainly not amount to more than a few degrees, so that some form of electrical resistance thermometer would have to be employed. If it had been possible to have the diaphone sounding a continuous blast, the test would have presented no serious difficulty. The capacity of the pumping engine was sufficient to furnish compressed air for a blast of six seconds per minute only, so that it was necessary to design a thermometer with so small a heat capacity that it would take up its final temperatures in that time. This was accomplished by making use of a very fine silk-insulated iron wire (1/1000 inch in diameter) wound in the form of a coil in specially designed frames, one of which could be inserted in a large valve on the compression side of the diaphone, and the other inserted in the trumpet about five inches from the vibrating piston. Each winding of the fine iron wire was supported at intervals by loops of silk cord so that no part of the winding was in contact with the solid frame-work. The heat capacity of the instrument was thus reduced to a minimum, that of the wire itself. By connecting the thermometer to a Wheatstone bridge and bridge-wire in the usual way, it was found possible to measure temperature-differences to 1/100 of a degree C., making use of a portable Weston galvanometer to obtain a balance. A third difficulty which had to be provided for was the temperature rise in each thermometer, due to the frictional (or "kinetic") heating of the air rushing past the wires. Owing to the differential connection of the two instruments, the two effects would tend to counteract one another, but to get rid of the difficulty entirely it was planned to take observations in the following way. First, a temperature difference would be taken with the diaphone sounding a note at a given pressure. Then the diaphone piston would be blocked and

FIG. 3.



Apparatus for the thermal measurement of acoustic output of diaphone. The skeleton construction of the iron-wire resistance-thermometers is clearly shown.

FIG. 4.

Acoustic survey carried out from a ship's boat. The phonometer is shown mounted at the bow of the boat. The results obtained are shown graphically in Chart I.

FIG. 5.

C. G. S. "Lady Evelyn." From this ship were taken the phonometer observations for the long range acoustic survey, the results of which are shown graphically in Charts II and III.

so adjusted that at the same pressure the rate of air-flow would be the same as when sounding. In this case, however, as no energy is converted into sound, and as the velocity of air past the thermometer wires is the same, the frictional heating would be as before. By taking the difference of the differential thermometer readings, we are enabled to eliminate the kinetic heating and thus arrive at the true temperature fall due to the conversion of compressed-air energy into sound.

SECTION 7. ON THE FOG-SIGNAL EXPERIMENTS CARRIED OUT AT FATHER POINT, QUEBEC, SEPTEMBER, 1913.

I now pass on to the actual details of the experiments which I carried out on the Father Point fog-signal during the month of September, 1913. Through the courtesy of the Department of Marine and Fisheries, permission was given to operate the diaphone at will for the purpose of the tests. Through the kindness of the Postmaster General, I was authorized to take up permanent quarters on the mail tender, "Lady Evelyn," stationed at Rimouski, and to make use of this ship in carrying out acoustic surveys in the neighborhood of the Father Point signal, a few miles away. Mr. H. H. Hemming,[16] at the time one of our McGill students, assisted in the experiments and proved himself invaluable in taking observations. Our regular routine was to leave Rimouski wharf every available morning on the acoustic survey. The ship was skilfully navigated over a series of courses under the guidance of her commanding officer, Captain J. B. Pouliot. Weather conditions (velocity and direction of wind, description of sea and sky) and sextant observations to obtain the position of the ship at stated times over various parts of her course were left in the hands of Mr. Hemming; air-temperature was provided for by a self-registering thermometer; through the kindness of Dr. Barnes I was able to install one of his self-recording marine thermometers for obtaining sea-temperatures. I personally undertook the phonometer readings which were taken at the rate of one a minute. I may say that the phonometer from the start proved to be a complete success and that the great progress made in carrying out, under practical conditions, measurements of sound intensity must be attributed to this achievement of Professor Webster. The fog-signal itself had only to be started by the Father Point light-keeper to continue running without further attention, the pressure remaining remarkably constant. As I have already pointed out, small fluctuations of pressure are with very little effect on the pitch of the note emitted. This circumstance, together with the smoothness and purity of the tone of the Northey diaphone, contributed very materially to the success of the acoustic survey. The results have been plotted on a series of charts and diagrams, three of which are reproduced in Charts I, II, and III.

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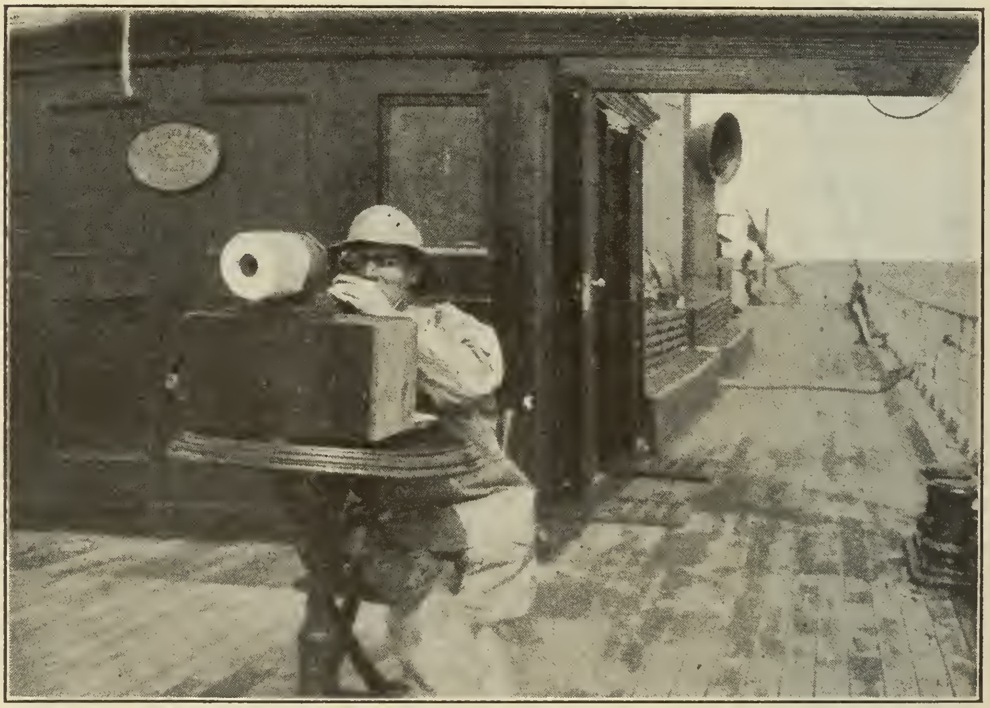
[16] Now Lieut. H. H. Hemming of the Third Field Survey Company, in active service in France.

FIG. 6.



Taking phonometer observations from the C. G. S. "Lady Evelyn" on a rainy day.

The acoustic surveys generally occupied the forenoon. About noon Mr. Hemming and I were put ashore at Father Point. Here we occupied ourselves in making preparations for the efficiency tests which were, after a few initial difficulties, duly carried out. The results obtained have enabled us for the first time to form some estimate of the amount of power delivered by a siren as sound. In the particular diaphone tested, operated under the best conditions, it was found that nearly two and a half horse-power (2.36 H.P. in one of the tests) may be so utilized.[17]

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[17] This estimate will, of course, have to be verified by further tests by different methods before being accepted as final.

Observations were taken with the diaphone sounding at different pressures so that the corresponding variation of acoustic output could be studied. Pressures were accurately measured by means of a mercury gauge. By measuring the fall of the gauge during a six-second blast it was possible to calculate the total air-consumption, knowing the volume of the storage-tanks and the rate of compression of the engines. In rating the efficiency of the diaphone it is necessary to adopt a somewhat arbitrary standard of reference. Air compressed to a given pressure and consuming a given amount of air per second is capable of doing mechanical work at a rate depending on the type of compressed-air engine used. That taken as our standard was, for purposes of discussion, one operating on an adiabatic cycle and capable of converting (in some way as yet undiscovered) *all* the energy of compressed air into sound. Efficiency rated in this manner I have called the *over-all* efficiency. Several series of observations gave fairly concordant results for the acoustic outputs at different operating pressures. In each of the tests, the over-all efficiency attained its maximum value at an operating pressure in the neighborhood of 20 lbs. per square inch above atmospheric. In one instance the maximum was nearly 6 per cent.; in another, after some adjustments to valves admitting air to the diaphone, the maximum rose to a little over 8 per cent. Full details of these tests will be found in a detailed account of the work which will be published shortly.

SECTION 8. ON FUTURE PROBLEMS IN ACOUSTIC ENGINEERING.

I think that it will be generally conceded from the description of the new methods of sound measurement which I have described, that the subject is in a fair way to being dignified by the title "acoustic engineering." It is also evident that a great deal remains to be done in this field. Regarding a sound-generator as a mechanical means of converting some sort of motive energy into sound, it is apparent that an over-all efficiency of 6 to 8 per cent. (or probably twice as high in the newer types of diaphones) leaves considerable room for improvement, although these numbers are many times greater than those derived for small-powered musical instruments. At this stage the questions which remain to be solved by future work may be stated as follows:

(1) Is there any limit (as in the case of ordinary heat-engines) to the proportion of power capable of being converted into sound-energy?

(2) How much of the sound-energy, once delivered as such at the narrowest part of the siren-trumpet, is wasted owing to losses in the trumpet itself and in the atmosphere outside?

To answer the first question it is necessary to undertake the mathematical theory of an ideal siren taking into account the equations of propagation of sound-waves of finite amplitude. There is no difficulty in estimating, according to the classical theory, the characteristics of a plane sound-wave transmitting power at the same rate per unit area as in the diaphone sounding under best conditions. The results are as follows:

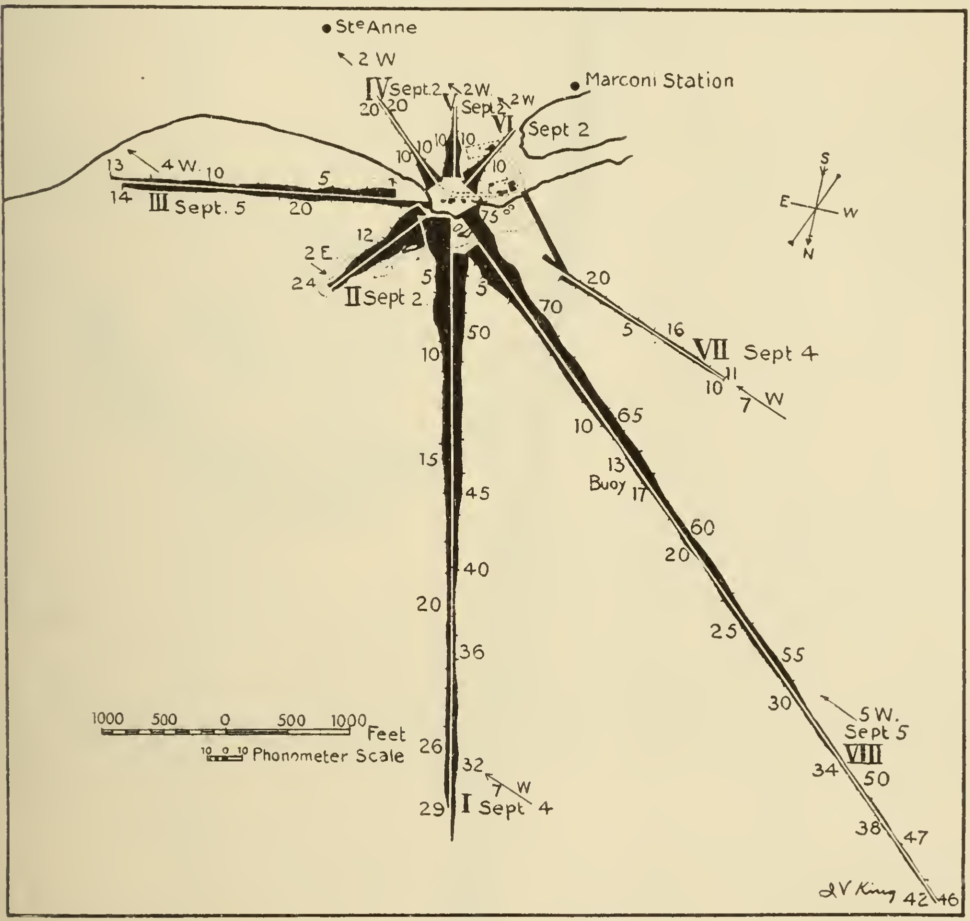
Pitch	175 complete vibrations per second.
Rate of transmission of power across 14 sq. in. (area of diaphone trumpet 5 inches from piston)	2.36 H.P.
Pressure amplitude	0.128 atmosphere.
Displacement amplitude	1.08 inches.
Maximum velocity of particle in sound-wave	99 feet per second.
Average velocity of air (calculated from rate of air consumption)	137 feet per second.

By an approximate solution of the exact equations of propagation, it may be estimated that a plane wave transmitting this amount of power unit area could travel only some distance between 9.7 and 10.7 feet before discontinuity sets in. In reality, this result will be modified by viscosity and thermal conduction, but the inclusion of these factors in the theory introduces unmanageable complications.

A little consideration enables us to understand how energy may be dissipated in a "finite wave," such as that we have just considered. Compressions and rarefactions of 1/10 atmosphere give rise to adiabatic heating and cooling of about 12° C. above and below the normal temperature. It has already been pointed out that there is a tendency for the compression to overtake the rarefied part of the wave so that ultimately these pressure inequalities will be much accentuated and will travel very close together. This gives an opportunity for equalization of temperature by thermal conduction with consequent dissipation of energy.

These were questions which I had proposed to attack theoretically and experimentally in a continuation of these tests to be carried out in the autumn of 1914, when the declaration of war put an end to all work of this kind by the diversion of activities to more pressing duties. The preliminary work which I have described this evening may be of some utility, I hope, in enabling engineers to proceed with a greater degree of confidence in the design and testing of fog-signal machinery. For instance, it is now possible to predict from a shop test what will be the performance of a given type of sound-generator. Formerly such a test

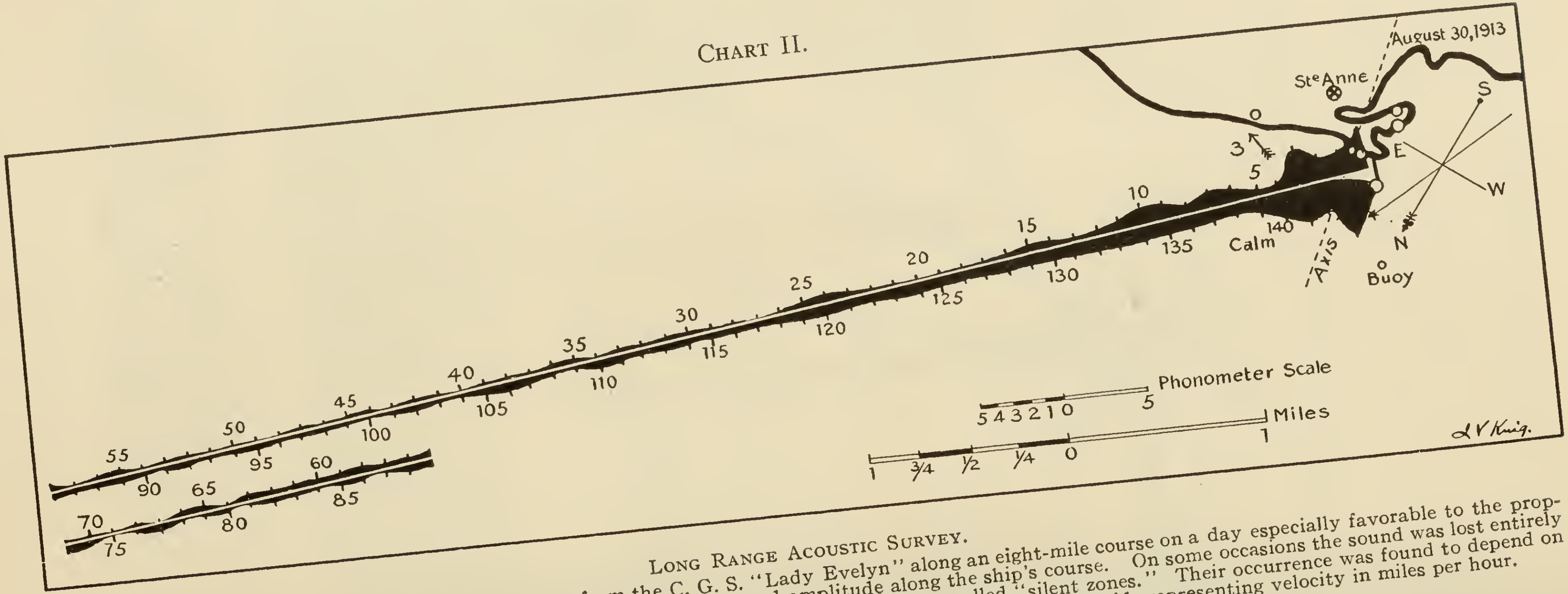
CHART I.



SHORT RANGE ACOUSTIC SURVEY.

The chart gives a graphical representation of the results of an acoustic survey carried out from a ship's boat in the neighborhood of the Father Point fog-signal with the Webster phonometer. The position of the ship's boat at each signal (identified by means of the numbers on the chart) was obtained by means of sextant observations. The phonometer readings at each position are plotted along ordinates at right angles to the outward and inward courses and are proportional to the pressure amplitudes in the wave. Wind directions and velocities (represented by arrows) are those registered at the meteorological station (near position 10 on Line VI). It was found that the effect of wind was by far the predominant influence on the variability of sound propagation.

CHART II.

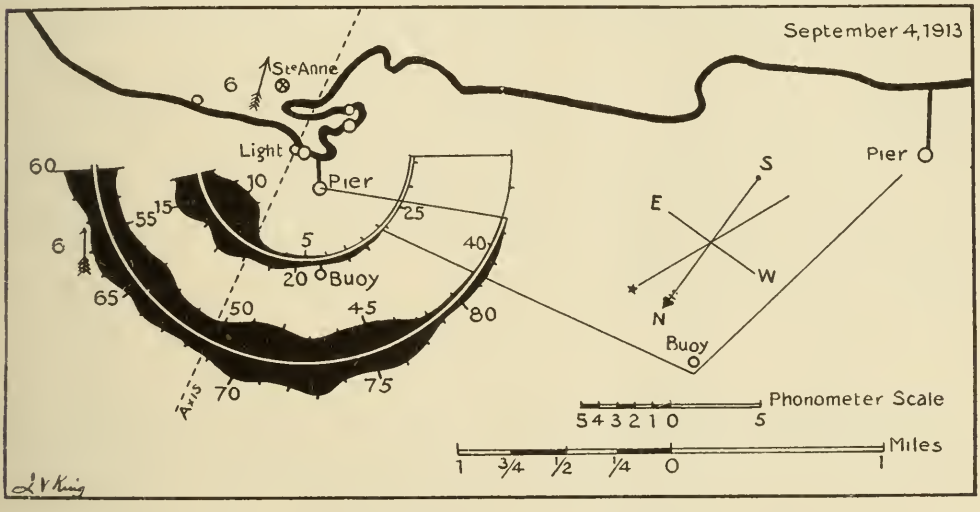


LONG RANGE ACOUSTIC SURVEY.

Observations taken with the Webster phonometer from the C. G. S. "Lady Evelyn" along an eight-mile course on a day especially favorable to the propagation of sound. Attention is directed to the periodic fluctuation of sound-amplitude along the ship's course. On some occasions the sound was lost entirely over certain portions of the course, to be recovered at a greater distance, giving rise to the so-called "silent zones." Their occurrence was found to depend on conditions of wind and weather. Wind direction is indicated by the arrows on the chart, the numbers alongside representing velocity in miles per hour.

could be determined only from an estimate from the ear, which is not able to discriminate differences of loudness when the intensities attain values far surpassed in fog-signal waves. It has frequently happened in the past that a new design of fog-alarm, thought to be promising from a shop comparison with an established type, has turned out to be an utter failure when tested by actual penetration of sound in the open atmosphere and large sums of money have been wasted in this way.

CHART III.



LONG RANGE ACOUSTIC SURVEY.

The ship was here navigated over circular courses with the fog-signal station as centre at distances of one-half and one mile. The phonometer readings are plotted along the inward and outward radii from the arc representing the ship's course. From observations such as these it is possible to estimate atmospheric propagation losses occurring between spherical surfaces at various distances from the fog-signal station. Wind velocities and directions represented as in Chart II.

By the use of the phonometer, fog-signal engineers may now study in greater detail the acoustic properties of proposed sites for the establishment of sirens by making use of an experimental diaphone installed on a lighthouse supply ship.

From a national or international point of view, the importance of the development of acoustic engineering will be readily understood when I state that in recent years a country like Canada spends per annum about two million dollars on the Lighthouse and Coast service. Of this amount as much as sixty thousand dollars has been expended annually on the installation of modern fog-signal apparatus.[18] That further developments in acoustic engineering may ultimately be the means of enabling governments to save annually in their fog-signal service large items of expenditure is of very mediocre interest as long as ships are wrecked and lives lost owing to accidents occurring in the fog. No effort should be spared to develop fog-signal machinery whose range and dependability in all kinds of wind and weather may be still further improved, and, in my opinion, there is in this domain room for a wide field of activity of the greatest human value and scientific interest.

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[18] According to figures taken from the Auditor General's Report, Ottawa, 1904–1912.

If the few remarks which I have been privileged to deliver this evening in the Institute which bears the name of the great Franklin himself should be instrumental in directing attention to this field of work, I feel that I owe the opportunity to the secretary, Dr. Owens, through whose activities, personal and editorial, I have been brought to realize that the Franklin Institute not only bears the name of the great American pioneer, but is also the embodiment of his living spirit.

The Source of Borax. ANON. (*U. S. Geological Survey Press Bulletin,* No. 307, February, 1917.)—The volcanic deposits on the east side of the Calico Mountains, at the edge of the Mohave Desert of California, include clays containing colemanite, a crystalline borate of lime.

Colemanite contains 50.9 per cent. of boric acid, 27.2 per cent. of lime, and 21.9 per cent. of water. The deposits near the Calico Mountains are believed to have been formed by replacement of limy beds that were laid down locally during the evaporation of lake waters, at intervals between some of the great outbursts of volcanic ejecta which formed so large a part of the Tertiary deposits. The boric acid was undoubtedly derived from fresh volcanic materials and carried to its present position by underground waters. The deposits are in two principal beds, each 5 feet thick and about 50 feet apart. These beds have been mined to a depth of 500 feet. All the borax produced in the United States is obtained from California mines, mainly from Lang, north of Los Angeles, and Death Valley. The value of borate ores produced in 1915 was nearly $1,700,000. The borax is made by heating the pulverized colemanite with a solution of sodium carbonate, forming the soluble sodium borate, which crystallizes.

THE FUNDAMENTAL PRINCIPLES OF GOOD LIGHTING.*

BY

P. G. NUTTING, Ph.D.,

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INTRODUCTION.

The historical side of the subject of good lighting is extremely brief. Artificial lighting is as old as the human race, but from the most ancient times until quite recently the one principle of lighting seems to have been the elemental one of a bare sufficiency of light. Only the simpler requirements of vision were recognized, efficiency in lighting was apparently not considered at all.

We are at present in a transition stage. The lighting industries paved the way for a great advance in lighting methods by making available an abundance of light. This means in effect that practically any desired *quantity* and *quality* of light are at our command. Further, the variety of lighting fixtures is an assurance that any desired *direction* and *ratio* of *scattered* to direct light may be had. Photometry is able to supply us with any desired data on intensity, brightness and distribution. Clearly then, the time is ripe for the research engineer to determine what lighting is most desirable. He cannot be expected to draw up a general scheme of lighting any more than a bridge engineer may produce a general plan for all bridges, but general principles may be determined and laid down for the guidance of illuminating engineers.

Good lighting is that which produces good seeing. This simple definition is both broad and precise; that lighting may be good, it is both necessary and sufficient that it produce good seeing conditions. The fundamental principles of lighting must, therefore, be derived from the requirements of vision and these in turn from the laws governing the sensation caused by any given exposure of the retina to light of any given flux density and density distribution. In other words, the passage of light from a source to a reflecting object and thence to the eye and retina is all governed by simple optical laws. Nothing occurring during that passage determines whether the seeing is good or bad—seeing conditions quite satisfactory to one eye might be quite intolerable to another. But the psychophysical relations between the light entering the retina and the sensation produced are all important.

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* Presented at the meeting of the Section of Physics and Chemistry held Thursday, November 9, 1916.

The following table may, perhaps, clear up the rather complex relation between lighting and seeing.

I. Good Seeing

Discrimination	*Acuity*	*Efficiency*	*Comfort*
Contrast in Detail	Sharpness of Detail	Seeing: Fatigue Light Economy	Lack of Fatigue Lack of Injury

(Related by Psychophysical Laws to)

II. Retinal Flux of Light

Intensity *Distribution* *Color*

(Deducible by Optical Laws from)

III. Objective Brightness and Contrast

(Deducible by Optical Laws from)

IV. Illumination and Reflecting Power of Objects.

(Deducible by Optical Laws from)

V Intensity and Position of Light Sources.

This bald outline of the principles of illuminating engineering emphasizes the importance of those psychophysical relations between light flux (in, say, lumens per square millimetre) at the retina and the corresponding perceptions. It indicates why good lighting cannot be defined in terms of illumination and reflecting power of objects illuminated, nor yet in terms of brightness and contrast in the field viewed. Retinal flux of light, even, is not sufficient to insure good seeing—the lighting must be such as to give the desired discrimination, acuity, efficiency and visual comfort, and a specification in terms of even retinal flux would fail to take account of the entire visual factor. Under certain conditions an increase in brightness and clearness may be obtained by actually *decreasing* the illumination.

Good lighting then is that which produces good seeing conditions, and good seeing is that which enables the average normal human eye to best distinguish details, in high light, half-tone and shadow, with at least moderate visual efficiency and comfort. Some vision under difficult seeing conditions is by no means objectionable, in my opinion, since over-protection is a sure cause of deterioration.

Now the ability of the eye to distinguish detail is not a fixed constant nor yet is it a function of a single variable, as in the corresponding case of the photographic surface; it depends upon (1) the absolute brightness of the object viewed, (2) upon the brightness or darkness of its surroundings (*i.e.,* upon peripheral vision), and (3) upon the brightness of objects just previously viewed (adaptation). Let us consider each of these relations in turn, concluding with some practical applications of the principles and data discussed.

VISION WITH STEADY, NEARLY UNIFORM, FIELD BRIGHTNESS.

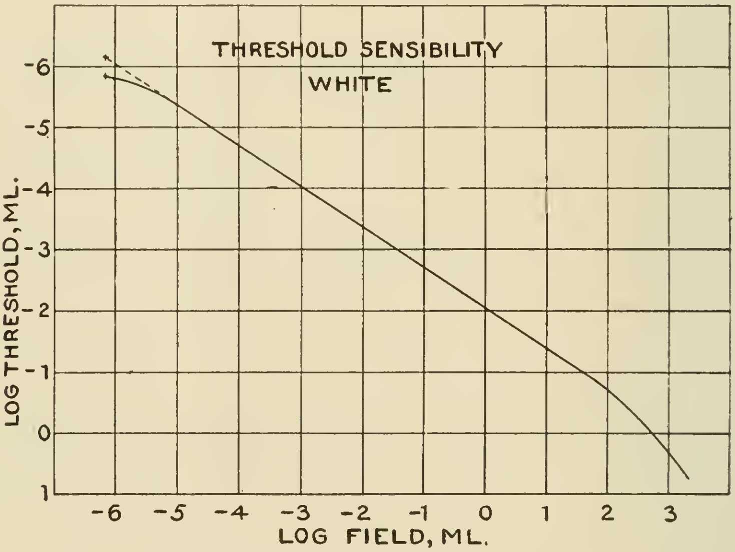
It is commonly known that the eye automatically adjusts its sensibility to the general brightness of the field viewed. Over a wide range of moderate intensities we are able to distinguish slight differences in light and shade about equally well. At lower brightness levels and at very high, considerably larger differences are the least that can be distinguished, while near the lowest perceptible intensities we can see but mere outlines. The whole range of intensities over which the eye operates, from the threshold of vision up to the blinding brightness which is the upper limit of adaptation, is roughly ten billion (10^{10}) to one, from 0.000001 millilambert at the threshold up to 10 lamberts. The latter brightness is about that of a sheet of white paper under direct normal sunshine. The clear noon sky, the full moon and a gas flame are each about one lambert in brightness; the lower limit for comfortably reading ordinary print is about 0.01 millilambert. Visual sensibility itself varies by a factor of about 10^7 while the field viewed varies by 10^{10}.

At any given general level of brightness, say that indoors under artificial lighting (about 1/10 m.l.), three visual constants are of chief interest: the lowest perceptible brightness, the least perceptible difference in brightness and the highest tolerable brightness. These constants are a measure of what we can see and of how well we can see at that brightness level.

Threshold Sensibility.—To obtain the lower limit of vision we first view a large white surface of known brightness until thoroughly adapted, then suddenly drop this brightness to another very much lower which is just visible. This threshold, of course, varies enormously with the brightness of the field to which the eye is initially adapted. The complete curve for white light is shown in Fig. 1. Plotted logarithmically the curve is a straight line from the threshold of vision up to about 100 m.l., then falls off more and more. The lower limit of adaptation is the threshold. The upper limit of adaptation, also where the least that can be seen is the whole, is where the threshold curve crosses the 45-degree line, that is, where the threshold brightness is equal to the field brightness. This is at a little over 10 lamberts.

This instantaneous threshold is a proper measure of the absolute sensibility of the retina, since it is determined by the condition of the visual surface and nerves. The absolute threshold at the lower limit of vision is a measure of the absolute photochemical reactivity of the retina. The straightness of the threshold curve is an indication of the simplicity of the relation between the state of the retina and the flux density upon it.

FIG. 1.

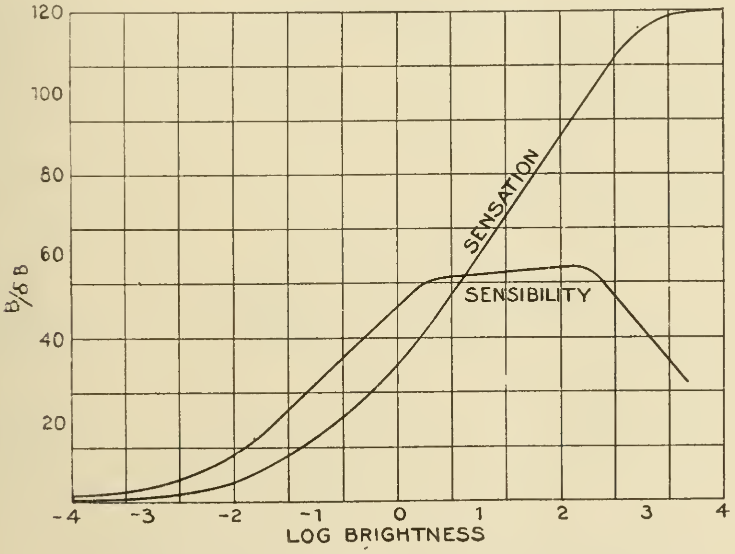


Variation of sensibility with brightness.

Discrimination.—Distinguishing slight differences in light and shade, picking up detail, is the characteristic function of the eye. This depends somewhat upon sharpness of definition and largely upon differences in color, but is principally a matter of contrast in brightness. Contrasts are ordinarily due either to differences in reflecting power or to partial shadows. Vision is best when contrasts are about 10 to 1, but is entirely comfortable with contrasts as low as 51:50 or as high as 20:1. Where contrasts are as high as 100:1, vision is not as acute and far less efficient than when they are moderate.

The relative efficiency of the eye under various contrasts and brightnesses is doubtless roughly measurable by accuracy and fatigue methods, but the fundamental datum in this field is the difference sensibility, resolving power for light and shade, discrimination, or whatever it be named. This datum is readily obtainable by photometric methods. It is the ratio (inverse) of the just perceptible difference in brightness to the brightness at which it is measured, B/dB. This is simply the reciprocal of the photometric difference determined twenty years ago by König and since then by numerous other observers. This curve of just perceptible difference has the general form of a sled runner. Recent work has but confirmed its general shape, established it in definite brightness units and determined the effect of time or adaptation.

FIG. 2.

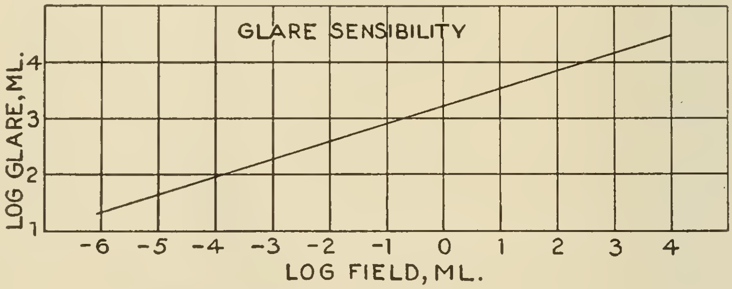


Discriminating power and sensation at various brightnesses.

The discrimination curve (Fig. 2) is the reciprocal of the fractional difference curve of the preceding slide. It rises slowly from the threshold up to a value of about 60, remains nearly constant for a considerable range, then falls rapidly at high, glaring intensities. The integral of the just noticeable difference, which is the fundamental relation between sensation and stimulus, is the sloping curve.

These curves may be compared with the corresponding reaction and discrimination curves for a photographic plate, a Seed 30, for example. The inclined curve is density of negative plotted against logarithm of exposure, the other is its derivative, the difference sensibility of the plate. The slopes are much steeper and more symmetrical than in the case of the retina, while the region of normal exposure is just about as extensive. The general similarity of the visual and photographic curves is very striking and indicates a similarity in the photochemical processes involved. The fact that the eye reaction is a function chiefly of intensity, while the photographic is a function of total energy (intensity × time), is doubtless due to restoring forces in the retina that are lacking in the photographic emulsion. The length of the initial slope of the eye curve indicates a distinctive initial phase of the reaction.

FIG. 3.



Glare sensibility at various brightness levels.

Glare Sensibility.—For any eye, adapted to any given brightness level, there is another much higher brightness just painfully bright, in which moderately contrasty detail cannot be distinguished. It would appear that only the roughest measurements of the glare limit would be possible, but since this datum is of the greatest importance to illuminating engineers, a determination was attempted. The three observers obtained quite concordant results, the mean showing a linear relation between log glare and log field brightness. (Fig. 3.)

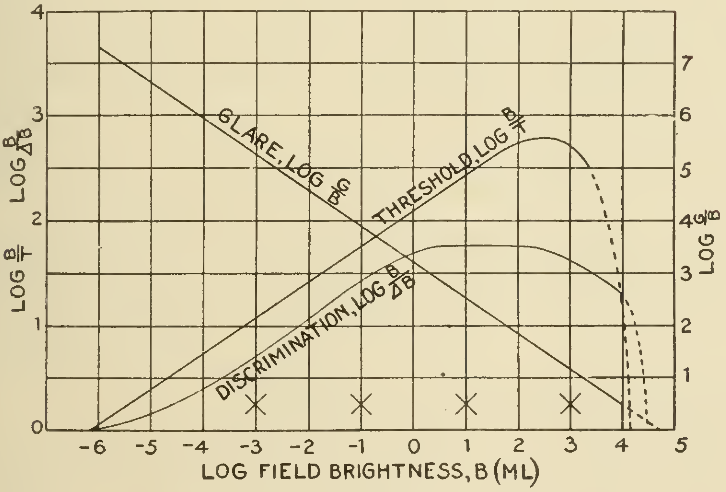
The range covered by the data is from near the absolute threshold (10^{-6} m.l.) up to nearly the upper limit of adaptation (10 lamberts). By practical experience we know that the eye is unable to adapt itself to a snow field under a direct sun and breaks down under long exposure. This, then, is the limit of the metabolic processes of the retina.

A brief summary of the data on threshold limit, discrimination and glare limit is given below.

Field Brightness.	Difference Fraction.	Discrimination Factor.	Threshold Limit.	Glare Limit.
0.000001 m.l.	(1.00)	1.0	0.00000093 m.l.	20.1 m.l.
0.00001	(0.66)	1.5	0.0000042	40.7
0.0001	0.395	2.5	0.000019	89.
0.001 (E.N.)	0.204	4.5	0.000087	86.
0.01	0.078	12.8	0.00039	400.
0.1 (I.N.)	0.037	27.0	0.00174	810. m.l.
1.0	0.0208	48.2	0.0081	1.66 l.
10. (I.D.)	0.0174	57.5	0.036	3.47
100.	0.0172	58.1	0.28	7.25
1000. (E.D.)	0.0240	41.7	2.15	14.45
10000.	(0.048)	(20.9)	(232.)	30.90

For example, an average eye adapted to a field brightness of 0.1 m.l. can just see a contrast of 1.037 : 1—the discrimination is about half (27/57) its maximum value. The deepest shadow in which it can see anything is 0.0017 m.l. in brightness and the brightest tolerable high light is 800 m.l.

FIG. 4.



Threshold, discriminating power and glare sensibility at various levels.

The illuminating engineer is chiefly concerned with four quite distinct brightness levels, namely:

0.001	m.l.	(E.N.)	Exteriors at night, street lighting.
0.01	m.l.	(I.N.)	Interiors at night, interior artificial lighting.
1.0	m.l.	(I.D.)	Interior daylight lighting.
1.0	l.	(E.D.)	Exterior full daylight lighting.

For comparison, these data have been plotted all together (Fig. 4). Glare and threshold are here plotted as multiples and fractions of the field brightness, while discrimination is plotted logarithmically. Running up any given ordinate, the curves show (1) the least perceptible contrast, (2) the lowest perceptible brightness, and (3) the highest brightness that can be viewed with comfort. The dotted portion of the glare curve is quite certain, that of the threshold fairly so, while that of the discrimination curve we know must end between these two.

VISION IN CONTRASTY FIELDS.

The data just given refer to vision with surroundings of nearly the same brightness as the object directly viewed. When this peripheral field is much brighter or darker than the centre, vision is seriously affected. In other words, central retinal sensibility depends upon the total light striking the retina and its distribution, as well as upon the light striking the fovea. Seeing in one eye is even slightly affected by the condition of the other.

A simple experiment with a tube shows the magnitude of the peripheral effect. If we view a blank space steadily through a black-lined tube 3 or 4 centimetres in diameter and, say, 50 centimeters long, held close to the eye, the spot seen through the tube grows rapidly in brightness until at the end of about a minute it appears 50 to 100 times as bright as the same spot seen with the unshielded eye. The light flux on the fovea is the same for both eyes. If the general level of brightness is low, this increase in apparent brightness is accompanied by a heightened discrimination, showing that the retinal sensibility is actually shifted along the discrimination curve by the shielding.

The opposite effect, with surroundings brighter than the centre of view, may also be demonstrated but requires laboratory apparatus. Both kinds of non-uniform field lead to visual discomfort, both in extreme cases cause a sensation of glare. Ives' investigation of photometric sensibility showed that the maximum of sensibility is obtained with nearly uniform brightness of the whole field of view. Glare we know to be impossible in nearly uniform fields, throughout the whole range of intensities to which the eye is capable of adapting itself.

We have obtained precise data on the depression of sensibility under various conditions of the surrounding field. Having the surrounding field dark and varying the angular size of the light central spot give curious results. If the central spot is not very bright, diminishing its size decreases the sensibility, while if it is quite bright the reverse is true. At intermediate brightnesses, varying the size of the central spot does not affect the sensibility.

EFFECT OF SIZE AND BRIGHTNESS OF SPOT ON SENSIBILITY.

Solid Angle of Bright Spots	Field Brightness 1.0 m. l.	 17 m. l	 170 m. l.	 600 m. l.
Full	0.0064	0.074	0.29	1.2
1.0	0.0050	0.074	0.27	1.4
0.1	0.0065	0.074	0.26	1.5
0.01	0.0090	0.074	0.22	1.5
0.001	0.0125	0.074	0.13	0.84
0.0001	0.0161	0.074	0.08	0.15

The effect is most pronounced at small solid angles, and the general trend of the change produced is best shown by the curves (Fig. 5).

Aside from its angular *size* and *brightness*, the effect of a glare spot on sensibility depends upon its *position* relative to the axis of vision. Data on relative threshold are given below for a field brightness of 0.1 m.l. and a frosted lamp about 1 lambert in brightness.

Angle	0°	10°	20°	30°	40°
Relative Threshold	0.11	0.17	0.26	0.42	0.65

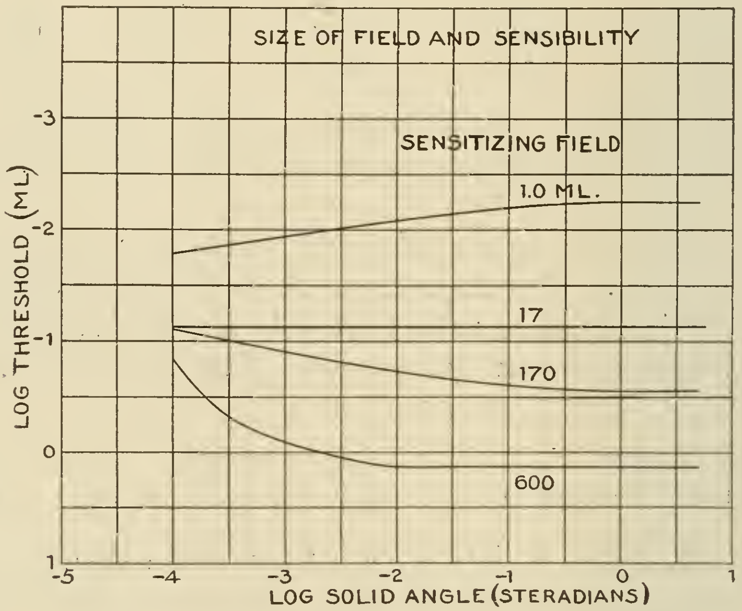
The (logarithmic) depression of foveal sensibility is a linear function of the angle with the axis. Beyond 50° no depression was perceptible.

The ocular discomfort caused by a lamp flame or filament within the field of view is largely a matter of intrinsic brilliancy and is relieved by a diffusing shade. The depression of sensibility, on the contrary, is a matter of total candle power and is not relieved by a shade which merely diffuses the light. If the brightness is held constant and the area (*i.e.*, total candle power) varied, then the depression varies as the square root of the candle power or area.

ADAPTATION TO VARYING BRIGHTNESS.

Vision is practically as comfortable and acute at the mean brightness of a well-lighted interior (0.1 m.l.) as in full daylight with a mean brightness level ten thousand times as high (1 lambert). The visual mechanism automatically adapts itself to the changed conditions by some means not well understood. If the brightness level is suddenly changed, adaptation is very rapid at first, then comes gradually to equilibrium. Adaptation curves have been run for times as great as sixteen hours. With our improved visual sensitometer and threshold method we have been able to study the important initial portion of these curves, readings of sensibility being taken after 0, 2, 5, 10, etc., seconds after exposure to light or darkness. In much ordinary vision the eye is constantly shifting from one object to other objects lighter or darker. If adaptation from lower to higher intensities occurred at the same rate as that from higher to lower, the net depression would be nil, but such is not the case.

FIG. 5.



Effect of size and brightness of spot viewed on sensibility.

The following table shows roughly the rates of increase and decrease in sensibility in an ordinary case. The data refer to the change from complete darkness to a brightness of 25 m.l. and vice versa. Twenty-five millilamberts is about the brightness of a sheet of paper in a well-lighted room on a bright day. It is a brightness quite blinding to an eye adapted to darkness, yet but a thousandth as bright as the average automobile headlight.

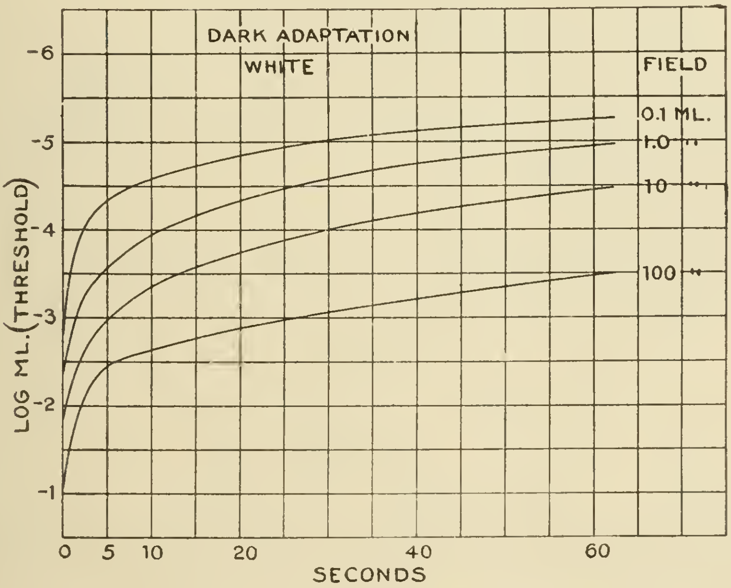
In the experiment the eye was sensitized to one level of brightness (0 or 25 m.l.) then suddenly exposed to the other and the (threshold) sensibility determined at intervals by the test spot method described above.

RATES OF INCREASE AND DECREASE OF SENSIBILITY.

Time	$B_0=0$, $B=25$ m.l. Sensibility decrease	$B_0=25$ m.l., $B=0$ Increase
1 second	2.1 times	1.6 times
2 seconds	4.2 “	2.6 “
5 “	16.2 “	7.6 “
10 “	58. “	14.4 “
10 minutes	120. “	20.9 “

For example, if an eye adapted to darkness be suddenly exposed to 25 m.l. its sensibility drops to 1/16 in 5 seconds and a subsequent rest of 10 seconds will by no means restore its sensibility. A great deal more data of this nature is desirable.

FIG. 6.



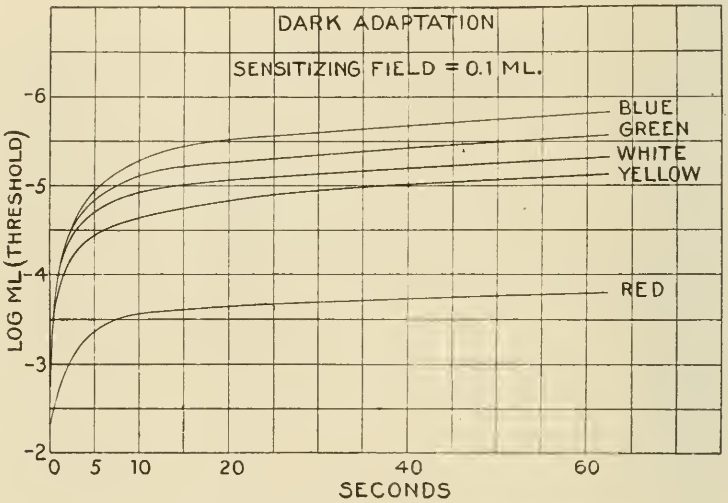
Dark adaptation. White light. Various initial brightnesses.

Dark adaptation has been quite thoroughly investigated. Starting with the eye sensitized to a given level of brightness, the light is suddenly removed and the rate of growth of sensibility in darkness is noted. This rate of growth varies with (1) the initial state of adaptation, (2) the color of the light used, and (3) the contrast used in the test spot. It varies also to some extent with the individual, his previous states of adaptation, extending back several hours, with the degree of attention exercised and other similar causes, but the first mentioned variables are by far the most important in practical problems.

In Fig. 6 are shown characteristic adaptation curves for white light and initial adaptation to brightness of 0.1, 1.0, 10 and 100 m.l. These curves run sensibly parallel for the first minute, but, of course, eventually merge and continue as a single curve similar to that of Fig. 6.

The initial adaptation is to some extent counteracted by the opening of the pupil. Precise shutter test measurements on the rate of pupil opening have yet to be made, but from adaptation curves run with and without a fixed artificial pupil we know that the greater part of the change in diameter occurs in the first half second. The pupil diameter corresponding to each steady field brightness has been determined as given in the following table. Both ends are, of course, horizontal since the pupil reaches definite maximum and minimum diameters.

FIG. 7.



Dark adaptation. Various colors.

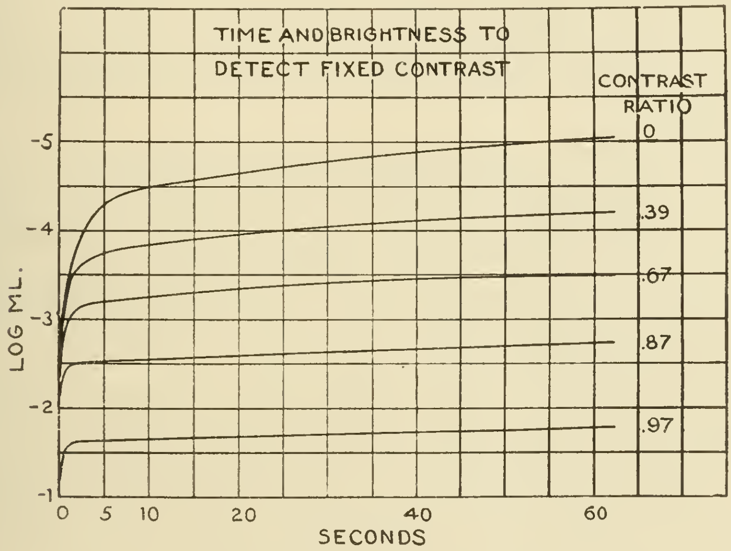
Field Brightness (m. l.)	.0001	.001	.01	0.1	1.0	10	100	1000
Diameter of Pupil (mm.)	6.1	5.9	5.7	5.4	4.7	3.7	2.8	2.1

Starting with the same initial sensibility but different colors, red adapts least and most slowly, yellow next, then white, green and blue (Fig. 7). Blue sensibility increases twice as rapidly as red and proceeds twice as far.

Most interesting from a practical standpoint are adaptation curves run with certain definite contrasts in the test spot. A strip of neutral gray film of known opacity is laid across the test spot and the time noted at which it just becomes visible over a spot whose brightness is constantly regulated. We thus obtain (Fig. 8) an adaptation curve for each degree of contrast. With contrasts so slight as 97:100 (3 per cent. absorption in the contrast strip) there is hardly any gain in visibility, while heavier contrasts increase more and more in a given time.

On entering a dimly lighted room from one brightly lighted, the heavier contrasts first become visible, then the more moderate contrasts. The faintest contrasts fail to become perceptible even after a long wait. Out-of-doors at night, not only detail in shadows but any detail involving weak contrasts is not perceptible.

FIG. 8.



Dark adaptation. Various contrasts.

If we take a vertical cross section (at 10 seconds, say) of a group of contrast-adaptation curves, there is obtained a relation between just perceptible contrast and brightness at constant time of adaptation. This is the Fechner fraction again; photometric sensibility curves have actually been obtained in this manner.

APPLICATIONS TO PRACTICAL LIGHTING.

The objective of all lighting is to secure visibility of detail in those objects to which attention is directed. The detail to be observed may be: (a) mere outlines of large objects, such as are required in riding along a country road at night, (b) the outlines of small objects, as in reading, or (c) the minutest detail which the eye is capable of resolving. As examples of Class C may be mentioned photo-engraving, drafting, sewing and many other arts and crafts where critical judgment is required.

For seeing of Class A but little illumination is required. The light of a high full moon supplemented perhaps by a little local lighting is ample if not ideal. Operating so near the threshold, the retina is incapable of rendering detail except with harsh contrasts. Little attention need be paid to the direction of the lighting or to the ratio of specular to diffuse light, since the eye is operating at low efficiency anyway. Spot glare should be carefully avoided, however, since the retina is in a supersensitive condition and but a little glare will so depress sensibility as to render objects invisible. Ordinary automobile headlights and lighting units visible at less than 30° from the horizontal should be carefully avoided.

Seeing of Class B represents the vast majority of ordinary working conditions, reading, writing and accounting coming under this class, as does the lighting of school-rooms, auditoriums and shops. Contrasts are ample, the observation of fine detail is not required. Careless lighting is only too tolerable and therefore really efficient lighting none too common.

The specification of a discrimination factor of not less than half the maximum is perhaps reasonable for this class of seeing. It follows that any illumination that will produce a brightness level of not less than 0.1 m.l. nor over 7000 m.l. is tolerable, although brightnesses ranging from 1 to 250 m.l. are to be chosen.

The really difficult problems in this class of lighting are providing the proper ratio of direct to diffuse light and giving both the proper direction. Comfortable, acute vision requires that there be neither extreme high lights nor dense shadows within the field of vision and that the details to be observed present sufficient but not too great contrast, that is, contrasts of over 50 : 49 and under 50 : 1. Indirect lighting will get rid of the shadows and extreme high lights, but almost completely suppresses contrasts, particularly on glossy or uneven surfaces. Glossy surfaces it covers with a light veil of specularly reflected light, uneven surfaces becoming less visible by suppression of shadows.

With bright daylight in the open, the scattered light from the sky contributes from about 16 to about 40 per cent. of the total light falling on a horizontal or vertical surface. On cloudy days nearly all the light has 180 degrees diffusion and on clear days shadows are lighted chiefly by sky light. The golden mean for good average seeing is probably not far from 30 per cent. diffused light.

If we view a landscape on an ordinary clear day through yellow, amber or green glass, the view will appear very much brighter and more clean cut. The old explanation was that the yellow glass cuts out the purple haze, but it does a great deal more than that—it eliminates the diffuse sky light in all shadows because these shadows are lighted by blue light, leaving the directly reflected sunlight almost unaffected because the blue in it is but a small part of its total luminosity. The consequence is that shadows are deepened and contrasts everywhere increased, producing a brightening effect. Viewing through blue glass has precisely the opposite effect.

While cutting down brightness with an absorbing yellow glass may produce the appearance of enhanced brightness, added light may produce the sensation of lowered brightness. If a room lighted by high, well placed direct lighting units be further lighted by a little highly diffused illumination, the sensation produced is one of lowered brightness due to increased brightness of shadows and general decrease in contrasts. In the black tube experiment shielding the peripheral retina from light produced a sensation of increased brightness fifty to one hundred fold on the unshielded portion, although the total light entering the eye was much less.

The proper proportion of direct to scattered light is readily obtainable in either artificial or daylight lighting. The lighting units must further be so disposed as to give a direction adapted to the service to be rendered. In art galleries the glossy surfaces to be viewed are plane and nearly vertical, hence high angle lighting is indicated. In machine shops, the glossy surfaces to be considered are largely horizontal cylinders and the lighting may well be of low angle and very diffuse.

In street lighting there exists a very persistent custom of leaving the illuminant in full view and of allowing a large fraction of the light to escape upward. A bright illuminant within the range of vision is a powerful depressant of visual sensibility, particularly if near the axis of vision, so that the customary arrangement is hardly conducive to visual efficiency. In interiors both very good and very poor lighting are common in both daylight and artificial lighting.

In the highest class of lighting (Class C, above), where the minutest detail is to be critically observed, only the very best lighting conditions will prevent visual discomfort and eye strain. Fine needle work requires perhaps as high class lighting as any. Interest centres upon a mass of fine bright images formed by the needle and fibres of textile goods. If all the light is diffuse, these images broaden and merge and shadows disappear. Vision is strained by the attempt to pick up faint contrasts just at the limit of the power of discrimination. The most suitable lighting is that limited to nearly a single direction and that quite elevated. What is seen is a mass of cylindrical images of the source, and if the source subtends but a small angle these images are sharp and contrasty.

In short, the very best seeing requires an abundance of nearly unidirectional light. The light from the sky through high, well spaced windows is very nearly ideal. Indirect lighting from numerous sources is very bad. Semi-indirect lighting with units closely assembled and at one side is probably the best form of artificial lighting. No part of any lighting unit within the range of vision should exceed 250 millilamberts in brightness nor should contrasts ordinarily visible exceed 100 : 1.

Our whole discussion has been an attempt to elucidate the principles of efficient lighting, efficient in the double sense of making the best possible use of the light and efficient in enabling the eye to operate under the most favorable conditions. Extremists have, on the one hand, tolerated any lighting that did not cause permanent injury to the eyes, and on the other have raised trivial objections to even minor causes of discomfort. I have no sympathy with either view; what should be done in my opinion and what is worth our best consideration and effort is the relief of our over worked and much abused eyes from the wear and tear of the bad lighting conditions which we have ourselves put upon them. It would be unwise and unnecessary to relieve them of all discomfort at all times—that would surely result in a deterioration of the adaptability of the eye itself. Our standard in my opinion should be the comfort of out-of-doors daylight lighting; abundant light 30 per cent. diffused and—by far the most important—but moderate contrasts anywhere. Under but tolerable lighting conditions the eye is wonderfully adaptable and efficient and it is to be hoped that within the near future it will be relieved of the many trying conditions under which it is now called upon to operate.

THE ORGANIC NITROGEN COMPOUNDS OF SOILS AND FERTILIZERS.*

BY

ELBERT C. LATHROP, Ph.D.

USUAL AND UNUSUAL NITROGENOUS SOIL CONSTITUENTS.

Histidine, hypoxanthine, cytosine, xanthine, nucleic acid, creatinine, cyanuric acid, or its isomer cyamelid, may then be considered to be organic nitrogenous constituents commonly occurring in soils.

Arginine, lysine, adenine, choline, trimethylamine may be considered at the present time to be nitrogenous constituents unusual to soils, inasmuch as they occur infrequently in soils. These compounds may either not be normally formed by the processes of change taking place in the soil, or if they are formed they are probably very quickly changed into other compounds, for example, arginine into ornithine and urea, or adenine into hypoxanthine. Regarding tetracarbonimid and urea no statement can be made at present.

THE CHANGES PRODUCED IN THE NITROGENOUS ORGANIC MATTER OF SOILS BY THE PROCESS OF PARTIAL HYDROLYSIS.

Having established the fact that a number of the simpler primary protein decomposition products are normally occurring soil constituents, likely to be found in all soils under agricultural occupation, it seemed desirable to see if it might not be possible also to demonstrate the presence in soils of compounds more complex than any of these. Two methods exist of determining this experimentally, first, directly, by isolation of the complex compounds, and, second, by isolation of their component units, produced by treatment of the soil after previously establishing the absence of these units in the untreated soil. The second method is the one employed in this investigation.

The soil treatment used in decomposing these more complex

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* Contribution from the Laboratory of Soil Fertility Investigations, communicated by Dr. Oswald Schreiner and published by permission of the Secretary of Agriculture.

Continued from page 206, February issue.

nitrogen compounds was steaming. The effect which moist heat produces upon pure protein material is that of partial hydrolysis, the extent of the hydrolysis depending on the temperature reached and the length of treatment. The effect which heat has upon soils is a subject which has been, and is, rather prominently before agricultural investigators. It is a subject which has been receiving increasing attention, particularly from the point of view of sterilization or partial sterilization of the soil. Since heat activates the changes going on normally in soils, it is obvious that a study of heated soils also throws light upon the biochemical changes taking place in soils under field conditions.

Notwithstanding the fact that some of the results obtained by some of the investigators[1] on this subject are contradictory, especially in regard to the effects of steam sterilization of soils on crops, they seem to warrant the following conclusions:

By steam-heating the physical, chemical, and physiological properties of soils are more or less altered. The chemical changes consist in the increase in soluble matter in the heated soils. This is partially of an inorganic nature, potash and phosphoric acid being mainly determined, but the largest increase is in the organic matter rendered soluble. Ammonia is formed by the reduction of nitrates to nitrites and ammonia, but especially from the decomposition of organic matter. Large amounts of nitrogenous matter are made soluble and apparently more available for plant use, and carbon dioxide is produced in large quantities.

The nature of the chemical changes observed by these investigators is not made clear, although a number of suggestions, or hypotheses, have been put forward. These concern themselves partly with an explanation of the increase in mineral constituents, due to altered absorption qualities for these constituents brought about by heat and by the greater hydrolysis or solubility of the minerals under the conditions of high temperature. Nearly all have particularly noticed the greater increase in soluble nitrogen and coincident with this the increase in soluble organic matter. It is these latter observations which have been the source of most of the speculations to explain the increase and decrease, as the case may be, of plant growth on soils thus heated. These views are usually coupled with the biological idea which furnished the motive for the experiment.

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[1] In this connection see the following: A. Baumann, 1887; Bolley, 1911; Darbishire and Russell, 1907; Deherain and Demoussey, 1896; Dietrich, 1901; Fletcher, 1910; Frank, 1888; Hérbért, 1889; Hiltner and Störmer, 1903; Hutchinson and Miller, 1911; Kasseroff, 1906; Kelly and McGeorge, 1913; Koch and Lüken, 1907; König, Hasenbaumer and Coppenrath, 1906, 1907; Laidlaw and Price, 1910; Lathrop, 1912; Lemmermann, Fischer, Kappen and Blanck, 1909; Liebscher, 1893; Loew, 1909; Loew and Aso, 1907, i, ii; Loges, 1886; Lyon and Bizzell, 1909, i, ii, and 1913; Peterson, 1911; Pfeiffer and Frank, 1896; Pfeiffer, Frank, Friedlander and Ehrenberg, 1909; Pfeiffer, Guttermann and Theile, 1910; Pickering, 1908, i, iii; Richter, 1896; Rudd, 1893; Russell, 1910; Russell and Hutchinson, 1909; Russell and Petherridge, 1912, 1913; Schmoeger, 1893; Schreiner and Lathrop, 1912; Seaver, 1909; Seaver and Clark, 1910; Selby, 1896; Stone and Smith, 1901, 1902; Stone and Monahan, 1904; Stuart, 1905; Vogel, 1914; and Wilson, 1914.

In no case has any definite compound been obtained, either as an end or intermediary product of the changes brought about by the heat, and the subject is left in the same state of indefinite generalizations in which soil organic matter or humus found itself in the course of the past half century. In view of this lack of knowledge concerning the chemistry of soil organic matter itself, and its transformations under ordinary conditions, it is not to be expected that changes like the above could have been clearly defined.

The investigations of the past few years have brought with them an increasing knowledge of the nature of organic matter, especially with regard to the isolation and identification of specific chemical compounds from soil, so that the biochemical changes taking place in soil are becoming clear. In connection with these investigations methods for the recognition or isolation of specific chemical compounds have been developed. With such knowledge at hand, it seemed possible to go one step farther and show the changes produced in soil organic matter in the process of sterilization by heat, and thus be able to interpret these changes.

THE SOILS STUDIED.

The soils used in this investigation are two types of the Coastal Plains Soil Province, known as Elkton silt loam and Sassafras silt loam. These two soils were collected from the same farm, about four miles east of Easton, Md., April, 1911. The samples taken were from several spots within a radius of 40 feet in each case and were collected in adjoining fields within 150 yards of each other.

Although these soils have the same geological origin, they are rather widely different in physical and chemical characteristics, and in fertility. The differentiation is apparently due to drainage conditions. While the two soils are very distinct in color, and in general agricultural value, the change from one to the other is frequently so gradual that it is difficult to draw a distinct boundary line. The samples taken are strictly typical of the types.

Analysis shows that these two soils contain practically the same amount of organic matter, the Elkton 2.25 per cent., and the Sassafras 2.24 per cent.; the former contains 0.13 per cent. of carbonates, expressed as carbon dioxide, and the latter only 0.03 per cent. The two soils are both acid to litmus paper, the Sassafras soil being slightly the more acid of the two. In regard to their oxidizing power and their catalyzing power, that is, their power to decompose hydrogen peroxide, they are both very weak, the Elkton showing none at all and the Sassafras only a little. They both contain practically the same percentage of total nitrogen. When the soils are boiled with hydrochloric acid and the different forms of nitrogen determined according to the method of Osborne and Harris (1903), the soils show only trifling differences. The results obtained by this method of analysis are presented in Table I.

TABLE I.

Different Forms of Nitrogen in Elkton Silt Loam and Sassafras Silt Loam. Results Expressed in Per Cent. of Total Nitrogen in Oven-dried Soil.

Form of Nitrogen.	Elkton.	Sassafras.
Per Cent. of Total Nitrogen in Soils	0.0859	0.0869
Total N in solution	91.83	91.08
N insoluble in HCl	8.17	8.92
N as NH_3	0.83	2.27
N as Amides	12.06	12.45
N as Melanin N	18.96	19.63
N as Diamino acids	5.53	7.17
N as Monoamino acids	54.45	49.56

From Table I it is apparent that the only difference worthy of mention is the fact that the Sassafras soil contains slightly more ammonia than does the Elkton soil, but this is much too small to account for the differences in fertility. It is apparent from all of the analytical data that, in a general way, these two soils are very similar in their organic composition, and that no methods of analysis, excepting the actual isolation of the various definite organic compounds which compose the organic matter, will show wherein this difference in their organic composition lies.

The methods of farm practice have been identical with these soils, and each has received the same kind of débris, manures, plant residues, etc., which by processes of decay go to form the organic matter of soils. If, therefore, differences in the organic matter of these soils are shown to occur, they must be the result of different processes of decomposition in the soils.

THE METHOD OF HEATING.

For the purpose of heating the soils an autoclave such as is in general use was employed. The autoclave is of copper, so constructed that it may be automatically kept at 30 pounds steam pressure for any given length of time. The soils were heated in one-gallon stoneware jars placed in the autoclave in a metallic rack, the jars standing one above the other, the lower one being about 4 to 5 inches above the bottom of the autoclave. These jars held approximately 10 pounds of soil. The soils were heated at 30 pounds pressure for 3 hours, at a temperature of about 135° C. The soils were treated with alkali just as soon as they had cooled to room temperature, so that only the changes caused by the immediate heating were under observation.

METHOD OF EXTRACTION.

Owing to the small amounts of organic matter in these soils and also to the fact that not all of this organic matter can be extracted, large amounts of soil were worked upon. Generally 40 to 50 pounds of soil, both heated and unheated, were extracted with 2 per cent. sodium hydroxide solution. No attempt was made to study the humus precipitate. The chief interest in the work centred in the nitrogenous compounds, especially those rendered soluble by heating of the soil. Such compounds would appear chiefly in the alkaline extract and later in the acid filtrate from the humus precipitate.

EXPERIMENTAL RESULTS.

In harmony with the observations of other investigators, the total amount of water soluble solids was increased by the heating. The soils by the bridge method showed the following content of total soluble solids: The normal Elkton soil, 184; the heated Elkton soil, 336; the normal Sassafras soil, 151; the heated Sassafras soil, 270 parts per million of dry soil. It will be noticed that the poorer soil, namely, the Elkton, showed the higher content in both heated and unheated condition. No further examination of the saline material was made.

By heating, the acidity of both soils was increased towards litmus paper. It should be noted, however, that ammonia and amines were also formed in the process of heating, as was indicated by the fishy odor upon adding the alkali in the process of extraction. The results obtained in isolating and identifying the organic nitrogenous constituents extracted from the heated and unheated soils are concisely given in Table II.

TABLE II.

Organic Nitrogenous Compounds Isolated from Unheated and Heated Soils.

Elkton silt loam.		Sassafras silt loam.	
Unheated.	Heated.	Unheated	Heated
Nucleic acid	Nucleic acid	Nucleic acid	Nucleic acid
Xanthine	Xanthine	....	Xanthine
....	Hypoxanthine	Hypoxanthine	Hypoxanthine
Adenine	Adenine	....	....
....	....	....	Guanine
....	Cytosine	....	Cytosine
Histidine	Histidine	Histidine	Histidine
....	....	....	Arginine
Creatinine	Creatinine	Creatinine	Creatinine

The results in Table II show only whether the organic compound was present or not. While no quantitative methods for the separation of these compounds from soils exist, owing to a great variety of difficulties which will not be discussed here, still in the work it was possible to distinguish between very small amounts and larger ones.

As seen from the table, the nucleic acid was found in both soils, in the heated as well as in the unheated samples.

Xanthine was found in both the heated and unheated Elkton soil, but in larger quantity in the heated soil. In the case of the Sassafras soil it was found only after heating.

Hypoxanthine was not found in the Elkton soil, but after heating a small amount was obtained. The Sassafras soil contained this constituent, but its quantity was much increased on heating the soil. In both cases the heating increased the amount which could be obtained.

Adenine was found in small amounts in the Elkton soil, but was not obtained from the Sassafras. Heating effected no change in either case.

Guanine was found only in the Sassafras soil and is of especial interest, since this is the first time that it has been encountered in soil.

Cytosine, it is interesting to note, was found only in the heated samples of both soils. It was obtained in much larger amounts in the case of the heated Sassafras soil than in the case of the heated Elkton soil.

Histidine occurs in both soils and a slight increase was noticed as the effects of heat.

Arginine, on the other hand, was found only in the heated Sassafras soil.

Creatinine was present in all cases.

NUCLEOPROTEIN DEGRADATION PRODUCTS.

If the principles discussed in an earlier section of this paper in regard to the breaking down of nucleoproteins and of nucleic acids be applied to the interpretation of the results obtained by heating the Elkton and Sassafras soils, it becomes evident at once that hydrolysis of the nucleic acids of these soils has taken place. This is evidenced by the fact that in each case there was a diminution in the amount of nucleic acid obtained from the soils, and by the increase both in quantity and in number of the nucleic acid bases.

In the Elkton soil unheated, adenine and xanthine were found; on heating, the amount of xanthine increased, adenine was found as before, and in addition hypoxanthine appeared. The hypoxanthine had been formed by a nucleoside containing this base. The fact that it did not appear in the unheated soil may be due to an arrested decomposition of its antecedents, or to the fact that it has changed into xanthine or lower nitrogenous compounds. Similarly, the appearance of cytosine in the heated soil is undoubtedly due to the same cause, the action of heat on antecedents containing it.

In the Sassafras soil the changes are even more definite. In the unheated soil the only base found was hypoxanthine, but after heating there appeared guanine, xanthine and cytosine, as well as a larger amount of hypoxanthine. The absence of guanine and xanthine in the unheated soil would seem to indicate that their antecedents were not subject to further decomposition under the existing soil conditions, or else they were rapidly changed into uric acid, urea, ammonia, etc.

These two soils, as already mentioned, have had the same general field treatment and have received the same kind of organic matter in the form of manures and crop débris, so that the nucleoproteins, nucleic acids, etc., which have entered into these soils, have been practically the same. The different results in the heated as well as in the unheated soils can only show that the decompositions occurring normally under the two different soil environments are biochemically different.

One difference between the two soils is found in the fact that the Elkton soil contains no antecedent compound which will yield guanine by heating. This fact may be explained by the assumption that the guanine antecedent, possibly guanosin, is changed to a xanthine antecedent in the soil. Color is lent to this assumption by the fact that xanthine is found in both the unheated and heated Elkton soil, while guanine, as well as xanthine, is found in the heated Sassafras soil.

Another difference is in the adenine. This is found in Elkton soil and not in Sassafras soil, and any antecedent bodies seem to be absent from the latter soil. Hypoxanthine, on the other hand, into which adenine or its antecedents may change, is absent from the Elkton soil but present in the Sassafras.

Cytosine antecedents are present in both soils. The fact that cytosine is not found in the unheated soils may again be due to the permanency of the antecedent under both soil conditions, or else to the presence of factors, either chemical or biochemical, which have transformed it into uracil. Whether uracil exists in these soils, or, in fact, any other soil, cannot be experimentally determined at present, owing to lack of characteristic derivatives or properties of uracil, although it seems probable that it must exist at least under certain conditions.

PROTEIN DECOMPOSITION PRODUCTS.

Two of the final products of protein hydrolysis appear in the present investigation. These are arginine and histidine. The latter was found in both soils, unheated and heated, but was found in greater amounts in the heated soil. Arginine was found only in the heated Sassafras soil. There is present, therefore, in the Sassafras soil a protein complex which acts as the antecedent of arginine. The question then remains, why is arginine absent from the unheated soil, and also, why is this antecedent body absent from the Elkton soil? Arginine, although a very common dissociation product of proteins, has, nevertheless, been found in only two other soils. This is rather peculiar in view of the fact that its close associate, histidine, has been found very often, a fact which is best explained on the supposition that arginine is very susceptible to change through biochemical influences. For instance, Kiesel (1909) found that the arginine in the juice of the green sprouts of lupine disappeared in the course of a four weeks' autolysis. In regard to the second part of the question as to the absence of any direct antecedent body, no very definite statement can be made, but it seems reasonable, since there is protein material in the soil, that the change of this material has not proceeded to such a stage that arginine could be produced by such a procedure as the one here employed. In other words, the biological factors in the Sassafras soil were such as to furnish an intermediary product which was dissociable by heat, and more readily decomposable in the soil. From this it would again appear that the biochemical factors are somewhat dissimilar under field conditions.

Concerning creatinine, nothing is known as to its immediate antecedent compounds and no special lesson can be learned from the occurrence of this constituent in these soils.

THE DECAY OF PROTEINS IN THE SOIL.

That constant decomposition of proteins is going on in agricultural soils is clearly shown by the two preceding investigations. This is evidenced, first, by the fact that a number of primary protein decomposition products are regularly occurring soil constituents, and by the additional fact that side by side with these simpler nitrogenous compounds there are present in soils, complexes, themselves proteins, or nucleoproteins, or very nearly akin to these. Such evidence shows the importance of a thorough knowledge of the biochemistry of the decay of protein materials in soils in finally elucidating the changes which take place normally in the organic nitrogenous matter of soils and the nature of the compounds which result from these changes.

This subject is not only of theoretical importance, but is of practical value as well. Not only do proteins from the débris of plants growing in the soil accumulate there, but there are added to most agricultural soils stable manure, organic fertilizers and green manuring crops. All of these manures contain considerable quantities of proteins or complexes closely related to the proteins. The question of the availability or agricultural value of these fertilizers is only to be answered either by directly determining the effects of the products of decay of these materials upon the plants growing in the soil or by determining by chemical means certain facts concerning their nature. It is obvious that a knowledge of the normal decay of protein material in soils will materially aid in solving such a problem.

This investigation was undertaken for the purpose of studying the changes taking place in the protein material of a high-grade organic nitrogenous fertilizer when added to an agricultural soil. Since ammonia formation is but one step in this process, it becomes of interest to know from what portion of the protein molecule this ammonia is formed; for how long the protein itself or the primary decomposition products of the protein can persist in the soil, and finally to gain some insight into the nature of the compounds formed by the action of the micro-organisms in their life processes.

THE PROTEINS STUDIED.

Dried blood, which was chosen for this investigation, is composed almost entirely of various animal proteins and the commercial product is of fairly constant composition. Abderhalden (1898) reports figures on the composition of the blood of cattle, sheep, pigs, horses, and goats, which show that a mixture of the blood of these animals should contain about 200 parts of solid matter per 1000 parts of blood. Of these solids about 54 per cent. is hemoglobin, and about 32 per cent. albumin, or approximately 86 per cent. is composed of proteins, exclusive of any nucleoproteins or nucleic acids, which undoubtedly are also present.

The dried blood used in this investigation was purchased in the open market and contained 13.92 per cent. of total nitrogen.

Two samples of dried blood were hydrolysed by boiling with hydrochloric acid and the various forms of nitrogen in the hydrochloric acid extract were then estimated according to the nitrogen partition method proposed by Van Slyke. The results so obtained are presented in Table III. Cystine nitrogen was not determined and the small amounts of cystine nitrogen in the blood would be included with nitrogen in the form of arginine, histidine, and lysine.

TABLE III.

The Forms of Nitrogen in Dried Blood and in the Experimental Soil. Results Expressed in Per Cent. of Hydrolysable Nitrogen.

Form of Nitrogen.	Dried Blood	Soil
Amide Nitrogen	6.854	7.008
Melanin Nitrogen	2.60	4.767
Arginine Nitrogen	7.517	7.601
Histidine Nitrogen	12.523	12.366
Lysine Nitrogen	11.517	10.093
Monoamino Nitrogen	57.057	58.220
Non-amino Nitrogen	1.479	0.312
Total	99.547	100.367

THE SOIL USED.

The soil chosen for use was a Norfolk fine sandy loam taken from a cantaloupe field near Raleigh, N. C. The soil was in a high state of cultivation and had received both mineral fertilizers and stable manure. It was found to contain 0.0301 per cent. of total nitrogen. The soil was passed through a 40-mesh sieve and dried in vacuum.

Forty pounds of soil were mixed with about three pounds of dried blood by sieving the two together until samples taken from different parts of the mixture gave duplicate analyses for total nitrogen. The total nitrogen in the soil thus prepared was found to be 0.8945 per cent. The ammonia in the prepared soil was found to be 0.0005 per cent.

The soil was made up to a 10 per cent. moisture content and was kept in a stoneware jar covered with perforated wrapping paper to exclude dust. The decomposition was allowed to proceed at the temperature of the laboratory.

During the first period of 18 days the soil was maintained at a moisture content of 10 per cent. and was mixed several times by hand during that period to promote aeration. Later on, however, the soil was restored to the 10 per cent. moisture content every 5 to 8 days, and on two occasions it was allowed to dry out completely. At each addition of water to the soil it was turned out of the jar and thoroughly mixed. The total length of the experiment was 240 days, during which time samples of the soil were taken at the following intervals: (1) 18 days, (2) 44 days, (3) 86 days, (4) 148 days, and (5) 240 days.

NITROGEN PARTITION.

By the use of the methods outlined the nitrogen was separated into the following: (1) Total nitrogen in the soil, (2) total nitrogen in hydrochloric acid solution, (3) ammonia nitrogen in the soil, (4) ammonia nitrogen in hydrochloric acid solution, (5) melanin nitrogen, (6) nitrogen precipitated by phosphotungstic acid, reported as arginine, histidine, and lysine nitrogen, (7) nitrogen in the filtrate from the phosphotungstic acid precipitate, reported as monoamino acid nitrogen and non-amino nitrogen.

By subtracting the amount of ammonia nitrogen found in the soil (3) from the amount of ammonia nitrogen found in the hydrochloric acid solution (4) the amount of nitrogen in the soil in the form of the amide group in proteins or as acid amides may be obtained. This is reported as amide nitrogen. The amount of nitrogen in the soil in the form of proteins or protein decomposition products, with the exception of ammonia nitrogen, may be obtained by subtracting the amount of ammonia nitrogen in the soil (3) from the amount of total nitrogen in hydrochloric acid solution (2). This is reported as " hydrolysable " nitrogen. The amount of nitrogen in all of the various fractions was determined by the Kjeldahl method, which does not include nitrate nitrogen unless large amounts of reducing substances are present: such may be the case, however, with some of the Kjeldahl analyses, and any nitrate nitrogen, therefore, included in a Kjeldahl determination would be reported as non-amino nitrogen.

In regard to the nitrogen reported in this investigation as amide nitrogen it might be stated that it is difficult to conceive in the present state of our knowledge of any other soil compounds than the various proteins which contain the amide group, or the acid amides themselves which would resist heating *in vacuo* with calcium hydroxide and subsequently split off ammonia on heating with hydrochloric acid.

The melanins are at present undefined and no significance can be attached to the figures obtained.

The nitrogen reported as monoamino acid nitrogen includes all nitrogenous compounds not precipitated by calcium hydroxide or not volatile in its presence *in vacuo,* not precipitated by phosphotungstic acid in the concentrations used and containing a free amino group which will react with nitrous acid to produce free nitrogen.

The greatest inaccuracies occur in the diamino acid fraction, and these are distributed between arginine, histidine, and lysine nitrogen. This group includes all nitrogenous compounds which are precipitated by phosphotungstic acid, excepting ammonia and melanin nitrogen.

The nitrogen reported as non-amino nitrogen includes all nitrogenous compounds not accounted for in the above and may include small amounts of nitrogen present in the soil in the form of nitrates.

The results obtained by the methods outlined are presented in Tables V and VI.

The amount of dried blood added to the Norfolk fine sandy loam is far in excess of the amount ever used in good agricultural practice. However, this amount was found to be necessary in order to obtain accurate analytical results and to assure differences of a large enough order between the various samples of soil analyzed; furthermore, it seemed desirable to add enough dried blood protein to the soil to render the small amount of soil proteins negligible, so that only the fertilizer nitrogen would be under observation. By reference to Table III, in which the results of the analysis by the Van Slyke method as applied to the mixture of blood and soil are reported, it will be observed that the figures obtained for the various forms of nitrogen correspond very closely to those obtained from the dried blood alone, except the figures for melanin and non-amino nitrogen, but the reason for this is not altogether clear.

AMMONIA FORMATION.

Assuming that ammonification of protein material in soil must precede nitrification and denitrification and that all loss of nitrogen in this investigation is due to ammonia evaporation, nitrification, or denitrification, and that free nitrogen is not split off from compounds other than nitrates or nitrites, then it is possible to arive at the amount of ammonia formation in the soil during each period of time. It should be stated that this is ammonia formation exclusive of ammonia assimilation, there being no way in which ammonia assimilation could be accurately determined in these experiments.

This ammonia formation may be calculated by the following equations:

Total $N - NH_3$ nitrogen in the original soil $= A$.

Total $N - NH_3$ nitrogen at the end of each period $= B$.

Then $A - B = X$, or ammonia formation during the period.

$\frac{X}{A} =$ per cent. of nitrogen changed to ammonia during the period.

In Table IV are presented the results obtained by the use of these equations.

TABLE IV.

Per Cent. of Total Nitrogen in the Soil Ammonified at the End of Each Period of Sampling.

Time in days from the beginning of the experiment.	Per cent. of total nitrogen.
18 days	18.72
44 days	54.03
86 days	72.66
148 days	78.13
240 days	78.92

THE RESULTS OBTAINED BY THE VAN SLYKE METHOD.

By comparing the results obtained by the Van Slyke analysis of each soil sample during the experiment with the results obtained on the original soil the amounts of gain or loss in the eight different forms of nitrogen can be arrived at. It is thus possible to determine how rapidly any particular form of nitrogen compound disappeared from the soil during the course of the decomposition and, further, to determine the relative amounts of nitrogen in these fractions in respect to the total amount of nitrogen present in the soil at the end of any period. When an increase in any particular form of nitrogen over the amount present in the soil during the previous period is observed, it is not possible in all cases to state the compound in which this nitrogen existed. But when a certain form of nitrogen shows a loss during a period it is an absolute indication that that particular kind of nitrogen was disappearing or had disappeared from the soil, although the rate could not be determined. The results obtained by this analysis are presented in Table V, in which the amounts of nitrogen in the various fractions are reported in percentages of the hydrolysable nitrogen of the original soil.

TABLE V.

The Forms of Nitrogen in the Soil at the End of Each Period. Hydrolysable Nitrogen in the Original Soil = 100.

Form of nitrogen	Original soil	Time in days from the beginning of the experiment				
		18	44	86	148	240
Amide nitrogen	7.008	7.515	6.025	5.429	3.454	3.222
Melanin nitrogen	4.767	5.080	4.374	2.276	1.391	1.698
Arginine nitrogen	7.601	5.162	3.041	1.857	1.342	1.395
Histidine nitrogen	12.366	12.975	5.547	2.912	2.382	2.010
Lysine nitrogen	10.093	7.610	1.110	0.429	0.528	0.972
Monoamino acid nitrogen	58.220	40.493	18.612	8.970	7.938	7.187
Non-amino nitrogen	0.312	1.120	1.675	2.191	0.738	0.297
Hydrolysable nitrogen	100.000	79.660	40.598	24.070	17.740	16.741

The figures presented in Table VI represent the relative amounts of the various forms of nitrogen in percentages of the hydrolysable nitrogen of the soil present at the end of each period. From this table the fluctuating composition of the hydrolysable nitrogen of the soil may be followed and the final composition of the hydrolysable nitrogenous matter of the soil may be established.

TABLE VI.

Forms of Nitrogen in the Soil at the End of Each Period. Hydrolysable Nitrogen in the Soil at the End of Each Sampling Period = 100.

Form of nitrogen	Original soil	Time in days from the beginning of the experiment				
		18	44	86	148	240
Amide nitrogen	7.008	9.555	14.840	22.556	19.471	19.246
Melanin nitrogen	4.767	6.375	10.773	9.453	7.657	10.910
Arginine nitrogen	7.601	6.477	7.491	7.717	7.567	8.333
Histidine nitrogen	12.366	16.276	13.663	12.099	13.421	12.006
Lysine nitrogen	10.093	9.550	2.710	1.784	2.979	5.809
Monoamino acid nitrogen	58.220	50.812	45.847	37.264	44.745	42.922
Non-amino nitrogen	0.312	1.410	4.125	9.102	4.160	1.774
Hydrolysable nitrogen	100.000	100.000	100.000	100.000	100.000	100.000

The figures presented in Table VII show the amounts of loss of nitrogen in each form from the soil at the end of each sampling period. The amount of loss is stated in percentages of the largest amount of any form of nitrogen in the soil at any time; for example, in the case of the amide nitrogen the amount is largest at the end of 18 days, and this figure is taken as 100. In this table the word " gain " indicates an increase in the amount of nitrogen over that present at the end of the preceding period.

TABLE VII.

The Percentage Loss of the Various Forms of Nitrogen in the Soil at the End of Each Sampling Period. The Largest Amount of Nitrogen in the Soil in Each Form = 100

Form of nitrogen	Time in days from the beginning of the experiment				
	18	44	86	148	240
Amide nitrogen	Gain	20	28	55	57
Arginine nitrogen	31	60	76	83	Gain
Histidine nitrogen	Gain	58	80	82	83
Lysine nitrogen	24	89	96	Gain	Gain
Monoamino acid nitrogen	31	67	84	86	89
Hydrolysable nitrogen	20	59	76	82	83

HYDROLYSABLE NITROGEN.

During the 240-day decomposition of the dried blood in the soil a loss of 83 per cent. of the total hydrolysable nitrogen took place. At the end of 86 days the loss was 76 per cent., showing that during the latter and longer portion of the decomposition experiment the amount of hydrolysable nitrogen which vanished from the soil was extremely small.

MONOAMINO ACID NITROGEN.

During the experiment the monoamino acid nitrogen diminished from 58 to 7 per cent., or a loss of 89 per cent. of the total monoamino acids originally present in the proteins. At the end of 18 days 31 per cent. of this form of nitrogen had vanished, while during the same time only 20 per cent. of the hydrolysable nitrogen was lost. Since the monoamino acids contain more than half of the total hydrolysable nitrogen, it would appear that the relative loss from each would be about the same. The fact that there is a difference of about 11 per cent. between the losses from these fractions leads to the supposition that nitrogen split off of the monoamino acids has been assimilated by the microörganisms in the formation of their protoplasm.

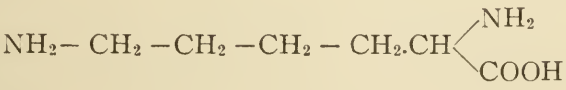
From Table VI it will be observed that the proportion of the monoamino acids present in the soil at the various times of sampling fluctuates. The lowest figure is 37 per cent. at the end of 86 days.

LYSINE NITROGEN.

The analytical results show that lysine disappears from the soil quite rapidly. At the end of 44 days 89 per cent. of the lysine originally present in the proteins has been decomposed, and at the end of 86 days, 96 per cent. During the remaining and longer part of the decomposition period there is a continual gain in lysine nitrogen, indicating that synthetic processes are at work.

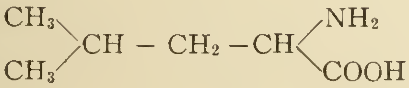
The gain in lysine nitrogen, after the original had practically vanished from the soil, is to be attributed to the action of the microörganisms in synthesizing some compound or compounds which give the analytical reactions for lysine. That this increase is due entirely to lysine cannot be stated, but lysine no doubt makes up a part of the gain observed.

It will be noted from Table VII that the two fractions which show the greatest amount of loss during the experiment are lysine nitrogen and monoamino acid nitrogen. It is not surprising that these two show the greatest loss when their chemical composition is considered. The monoamino acids are straight chain acids with the amino group in the alpha position to the carboxyl group. Lysine, a diamino acid, is also a straight chain acid containing two amino groups, one in the alpha position to the carboxyl group and one at the extreme end of the chain from the carboxyl group, or in the omega position. The relationship between lysine and the amino acids may be clearly shown by presenting the structural formulas for lysine and for leucine, for example:



$$\mathrm{NH_2-CH_2-CH_2-CH_2-CH_2.CH}\begin{matrix}\mathrm{NH_2}\\ \mathrm{COOH}\end{matrix}$$

Lysine.



$$\begin{matrix}\mathrm{CH_3}\\ \mathrm{CH_3}\end{matrix}\mathrm{>CH-CH_2-CH}\begin{matrix}\mathrm{NH_2}\\ \mathrm{COOH}\end{matrix}$$

Leucine.

However, it is observed that the lysine vanishes more quickly from the soil than the monoamino acids. This may be due to the fact that the omega amino group of the lysine exists free in the molecule of the native proteins which occur in the dried blood. Under such conditions this group is subject to deaminization by the action of the microörganisms before hydrolysis takes place, while in the case of the monoamino acids hydrolysis must precede deaminization, since these acids are linked in the protein molecule in anhydride structure. Furthermore, if the omega group be split off from the lysine while it is still a constituent part of the protein molecule it is changed into an amino acid with but one amino group and would be determined analytically as monoamino acid nitrogen.

From Table VI it will be observed that there are very marked fluctuations in the proportions of lysine nitrogen in the soil at the end of each period. The lowest amount occurs in the soil at the end of 86 days, which was the low point for monoamino acids. The final amount is about half that originally present in the dried blood.

HISTIDINE NITROGEN.

At the end of 18 days the histidine nitrogen showed a gain. Although the compounds which cause this increase cannot be arrived at, it is possible that they are, in part at least, the purine and pyrimidine bases, which by the analytical methods would be classed as histidine nitrogen. It is well known that the protoplasm of microörganisms is made up of considerable amounts of nucleoproteins and nucleic acid, which on hydrolysis would yield the purines and pyrimidines.

At the end of 44 days 60 per cent. of the histidine nitrogen had disappeared; at the end of 86 days, 80 per cent.; and after 240 days, 83 per cent.

The proportion of the histidine nitrogen in the soil at the various times of sampling is about constant, with the exception of the 18-day sample.

ARGININE NITROGEN.

After 18 days 31 per cent. of the arginine had vanished from the soil, while at the end of 148 days 83 per cent. had gone. From the 148th to the 240th day, a period of 92 days, a gain in arginine nitrogen is observed. This may be due to nitrogen in the form of arginine, or nitrogen in the form of compounds which give the analytical reactions for arginine. It is nitrogen formed by the action of microörganisms, probably a synthesis of protoplasm, and possibly in the form of proteins.

The relative amount of arginine nitrogen shows little fluctuation throughout the experiment and is a little greater at the end of the experiment.

AMIDE NITROGEN

The analysis of the figures for amide nitrogen brings out some interesting points. After 18 days there is an increase in amide nitrogen. It may be safely assumed that the compounds which this increase represents are acid amides, formed by the action of the microörganisms, existing in the soil either free or combined in the molecule of some new proteins contained in the protoplasm of the organisms. That there was actually an increase in this form of nitrogen after 18 days was, however, unexpected, since it is well known that microörganisms when grown in solutions of acid amides can use them for the building up of their protoplasm, and, furthermore, Jodidi (1912) has shown that acid amides are very easily and quickly ammonified when placed in an agricultural soil. It was therefore expected before the results were obtained that the amide nitrogen would be among the forms which would most quickly disappear from the soil. From Tables V and VII it will be observed that this fraction disappears least completely and most slowly.

The question arose as to whether the soil used was capable of ammonifying acid amides. Consequently one gram of pure asparagine, one of the two acid amides considered to be present in the protein molecule, was added to 100 grams of the air-dried Norfolk fine sandy loam to which no dried blood had been added. The soil was made to about a 10 per cent. moisture content and allowed to stand for four days. On analysis for ammonia it was found that the soil had converted 73.4 milligrams of asparagine nitrogen into ammonia nitrogen in this time, or, in other words, the soil in four days had ammonified 39.3 per cent. of the total asparagine nitrogen. This shows that if acid amides were free in the soil they would have been to a very large extent converted into ammonia during the 18 days of the experiment, and points unquestionably to the fact that the increase in this form of nitrogen is due to the synthetic action of the microörganisms in the building up of their own protoplasm.

(*To be continued.*)

Inclosed Arc-Lamp Market Vanishing. ANON. (*Electrical World,* vol. 68, No. 19, November 4, 1916.)—With the advent of the gas-filled incandescent lamp the future of the ordinary inclosed arc lamp has dwindled away. Ordinary tungsten lamps of the vacuum type had been competing with the inclosed arc lamp, but not with the degree of success that has attended the gas-filled unit. This new type of lamp has superseded the ordinary enclosed arc lamp for both street and factory lighting.

The new incandescent lamp has replaced the arc for a number of reasons. In the matter of annual cost and upkeep there has been considerable discussion, but it is now rather generally conceded that the gas-filled unit is more economical than the inclosed arc lamp. In the matter of outages and safety to trimmers the new lamp, of course, is superior. Furthermore, there are no carbons to deal with in incandescent lighting. Another reason, however, that has had no little share in popularizing the incandescent lamp is the development of ornamental lighting standards. The ornamental standard of both the single lamp and the cluster type has grown in popularity since the incandescent tungsten lamp was introduced. The luminous arc, however, has also become popular and is being used in large cities.

Moving-picture houses and theatres are now the largest purchasers of arc lamps, but there, too, the incandescent lamp is beginning to compete so that there seems every reason to believe that before long the inclosed arc lamp, as it is known, will be a thing of the past.

Well-Unit Water Supply. ANON. (*Engineering News,* vol. lxxvi, No. 24, December 14, 1916.)—For a number of years the city of Aurora, Ill., has obtained its water supply from a group of five wells. With the rapid increase of population in the past few years it became necessary to secure an increased supply. After investigation the city officials decided that instead of sinking more wells near the water-works it would be advisable to adopt the well-unit system. This consists of a number of deep wells distributed throughout the city, each operated by an independent pumping unit that delivers water directly into the mains. The wells are so located that the water pumped at each point has the shortest possible travel before being consumed, thus reducing to a minimum the friction loss in the mains. For this reason the wells are located usually near street intersections so that water can be pumped in four directions.

At present three of these new wells have been drilled. Their depth is approximately 2000 feet. A combination deep-well turbine and booster pump is used, directly connected to an alternating-current motor, the current for which is purchased. To increase the pressure in the mains for fire purposes the vertical deep-well unit will operate in series with a single-stage, double-suction, horizontal, motor-driven centrifugal pump. A pump efficiency of 70 per cent. has been realized.

THE PRODUCTION OF LIGHT BY ANIMALS.*

BY

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THE FIRE-FLIES OR LAMPYRIDÆ.

The best known, most widely spread and altogether most classic object of study for animal luminosity is without doubt the "fire-fly" and its larval form the "glow-worm." It is not a "fly" nor is it a "worm," but belongs to the family Lampyridæ of the order Coleoptera commonly known as the beetles. A typical form is seen in Fig. 1, A and B.

It is a large group of many genera and hundreds of different species scattered all over the world, from the hottest tropical countries to the frozen swamps whose tops are thawed out in summer, at which time they support a good fauna and flora.

As is natural, the form and habits of so large and widely distributed a group are subject to many variations and some of the species show no light at all on their bodies, while others glow from many parts of the body where light organs are formed. Several species can be found living in the same terrain in almost any region of the world.

In general form and appearance and in size these beetles show but little variation. It may be said that nearly all of them are from six to twelve millimetres in length and that the adults are of a moderately elongate form. The head is wholly or partly covered by a projecting and gracefully curved overhanging edge of the thoracic integument (see Fig. 1) and the antennæ are long and slender.

In color they are dark, usually black or brown that may be striped longitudinally with gray or white. At the anterior edge of the thorax a certain amount of dull yellow marked with red is usually present. Some have a uniform silvery gray as the body color, while a few are marked or mottled with white. Fig. 2 shows several varieties.

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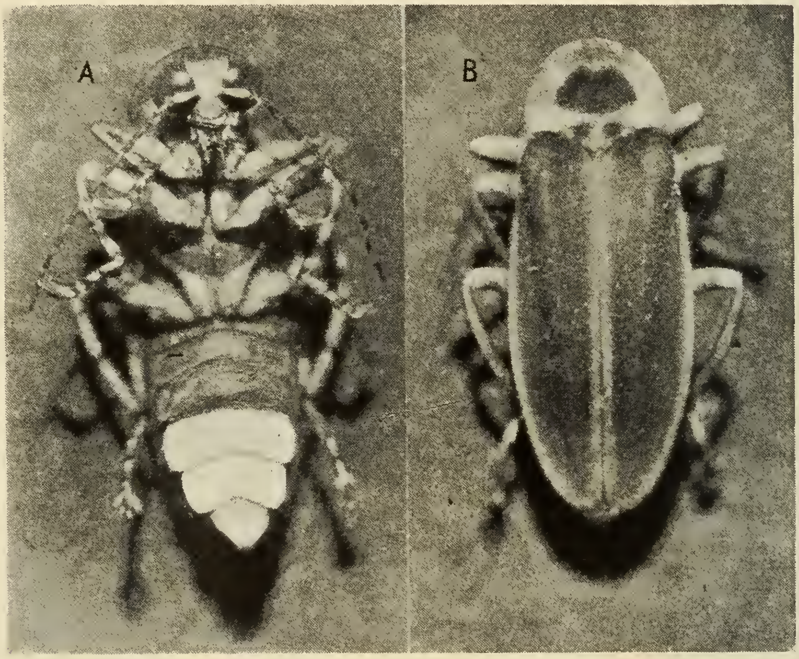
* Continued from page 220, vol. 183, February, 1917.

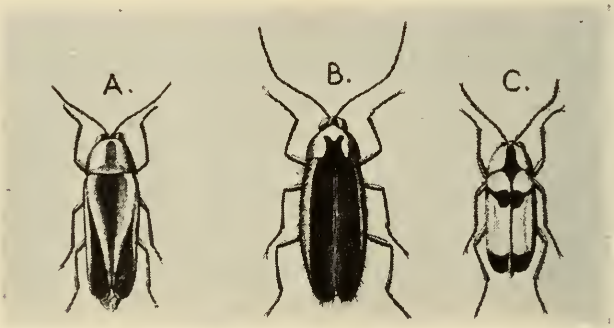
The larvæ are usually more elongate, are plainly segmented and crawl on the ground, this giving them the name of "glow-worm" (see Fig. 3). The back is dark and the head retractile into a cavity in the thorax. These larvæ live in dark, damp localities in swamps or on the edges of woods and thickets, crawling over the ground or on leaves and grass (see Fig. 4). They are carnivorous, eating only snails and slugs, and are nocturnal

FIG. 1.



Photograph of dorsal (B) and ventral (A) views of an alcohol specimen of *Photuris pennsylvanica* male.

FIG. 2.

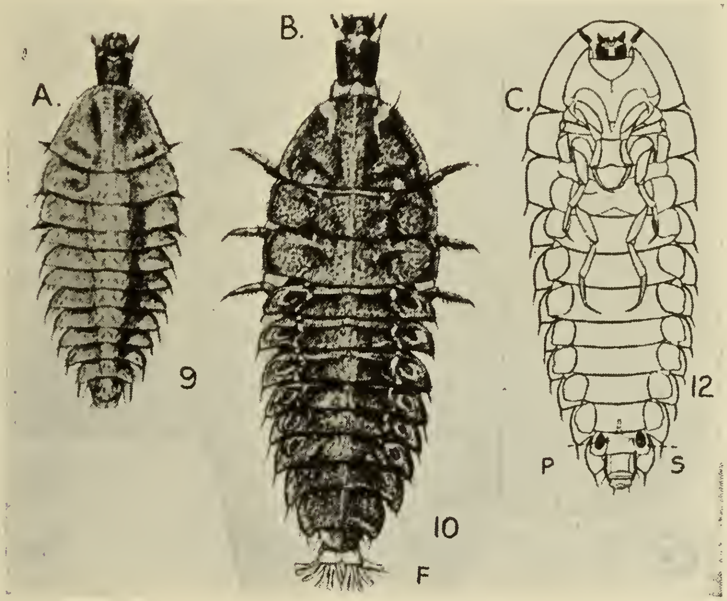


Figures of three exotic lampyrids (fire-flies). A, *Photuris transversa*. B, *Photuris villosa*. C, *Photuris alternans*. (From Henneguy.)

in their activities. During the day they sleep under dead leaves. In the more northern climates they hibernate during winter in mould, or under logs, or in the ground.

When about to pupate the larvæ of most of the species build a cell on the surface of the ground under dead leaves and change their skin to become the cream-colored pupæ which cannot walk but lie inert for a week or more until the skins are cast to produce the adult insects. Fig. 5 shows the pupa of one species. In some tropical forms the pupæ are attached to the side of a tree some little distance above the ground.

FIG. 3.



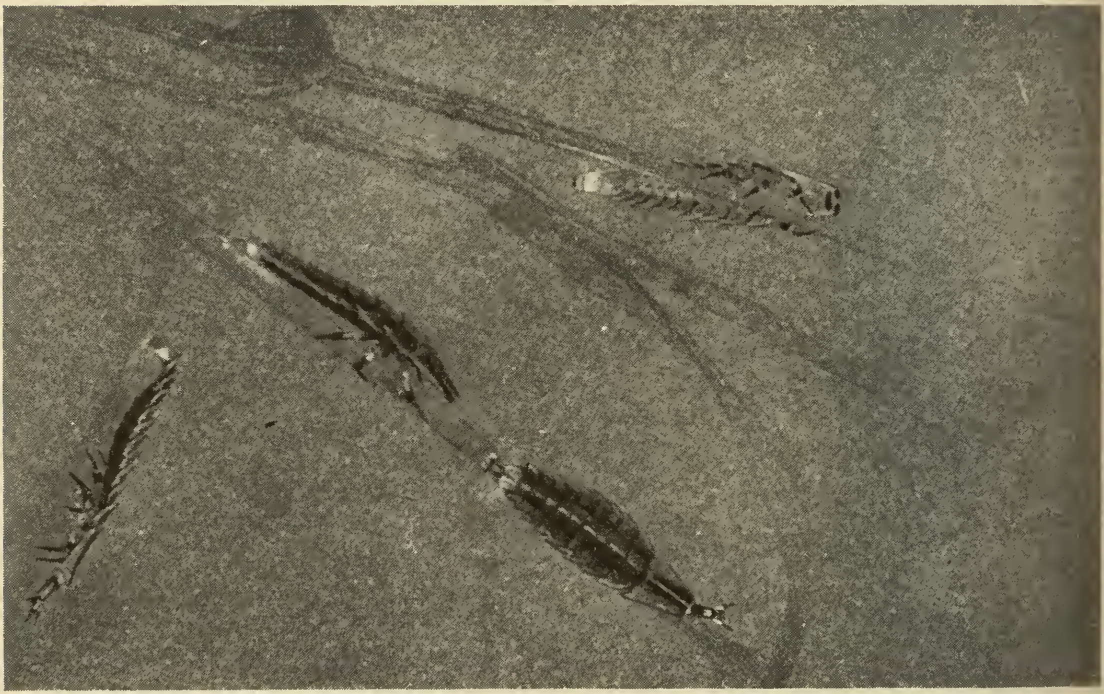
The larva of *Photuris pennsylvanica*. A, first instar at time of hatching. B, adult; not magnified as much as A. C, adult, ventral view, showing the positions of the larval light organs (p). (After F. X. Williams.)

The adult insect emerges in late spring or early summer in colder latitudes or in the wet season in tropical countries. After hatching and drying its skin, it moves about to seek its mate and when the female is fertilized she lays her eggs, in early or middle summer in New Jersey. These eggs are laid in mould around the roots of grasses and they take some time to hatch. When the young larvæ emerge they look much the same in form and color as the older ones and are ready almost at once to begin eating snails. This process is very interesting and will be dealt with on a following page.

After growing all summer and fall the animal hibernates. It is late in the fall before it goes into winter quarters and a warm spell in winter may bring it out for a few days at any time. It emerges in spring in March or April and passes the summer eating and growing. Wet weather is favorable, but very dry weather prevents it from moving about or catching snails which also seal up their opercular valve and hibernate when it is very dry.

A second winter is usually passed in the larval state and upon emerging from this rest the animal stores fat and goes into the pupal stage about May 15th–20th, building its little cell on the surface of the ground and under leaves or mould. The cell is built with a mixture of clay and saliva and is made of strands of this material that somewhat resemble very thin earthworm casts. Only a lattice-like cover is built, the ground being scooped out to form the lower wall. In this cavity it lies inert on its side and partly curled up. Its tissues appear swollen between the segments and assume a dull whitish color.

FIG. 4.

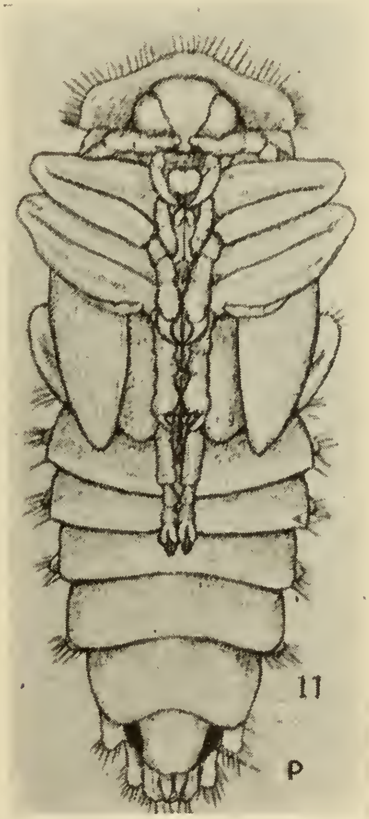


Larvæ of *Photinus sp.* (probably *consanguineus*) in their habitat at dusk. Drawing from nature by Bruce Horsfall.

In a short time the skin is cast and the light-colored pupa is revealed. Its powers of movement are extremely limited. About eight days is the time that elapses before it again changes its skin and the adult insect crawls out.

The question of the food and the manner of feeding of the larvæ of Lampyridæ has been carefully studied and described by Newport, Henri Fabre and R. Vogel. It appears that during its entire life, from its first hours after hatching until it is ready to pupate, the larva of *Lampyris noctiluca* feeds on nothing but pulmonate mollusks, both the naked kinds, such as *Limax* and *Arion,* and the forms that possess a shell, as *Helix* and its allies.

FIG. 5.



Pupa of *Photuris pennsylvanica.* The larval light organs still persist at P. (After F. X. Williams.)

Its method of securing this food is essentially the same at all times, varying only slightly and in a quantitative way according to the relative sizes of the larva and its prey and the condition of strength and hunger of the larva. The larva cautiously approaches the snail or slug with extended head and widely opened jaws. Seizing a favorable moment, it quickly bites its prey as near the head as possible and then moves back. The bite is repeated, sometimes for as many as twenty times. The snail soon shows signs of distress and in one or two hours, or sooner, becomes torpid as though narcotized. Its heart beats slower and breathing slows down and stops. After a short time it dies.

This would indicate that it had been poisoned by the bite. Experiments tend to show that this is true. It requires many bites by a small larva to overpower a large snail, and few bites for a large larva to kill a small snail. Also, if a larva is allowed to bite several snails without feeding on them and is then given a fresh one it does not readily overcome it by many bites, although its first victim is soon dead from its single attack.

Further, a brownish fluid from the midgut is seen to come from the mouth of irritated larva, as well as to be ejected when biting the snails. This fluid when dried on the slide shows a hard drop that clings to the glass and cracks with the drying as egg albumen would. Also, when stained it takes eosin intensively in the same way, and other tests also indicate that it is a proteid. Sections of the midgut show this material as granules that come from the cells, so that we may look upon it as a proteid poison.

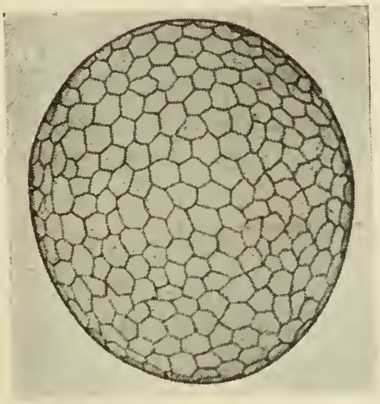
When the prey is dead the larva begins to feed upon it. It does this by chewing the flesh with its rough mandibles and ejecting more of the brown fluid. Under the influence of the chewing, and particularly of the fluid, the flesh turns brownish and dissolves into a structureless brown broth that contains no fragments of cell or nuclear material. This fluid is then sucked into the digestive tract.

The larva becomes gorged with this material and after hours of feasting retires in a sleepy condition to further digest and assimilate this food. So full is it that its former flat shape is now rounded. What is true of this form in regard to its feeding is probably true of most of the other Lampyrids. Possibly we may find some other kinds that attack other prey, as earthworms, for instance. Vogel found that starving larvæ would chew and digest small bits of veal, which was dissolved in the same way as snail flesh under the influence of the brown fluid.

POSITION AND NUMBER OF LIGHT ORGANS.

The lights vary in number and somewhat in position in the various species. In the first place, this power is already seen in the earliest moments of the creature's life, in the egg. This single cell sheds a pale glow when first laid in the few forms where it has been possible to study it. This is true of the egg even before laying it in mother's body. When laid it is of a light pinkish or yellowish hue and its surface is marked by tiny facets (see Fig. 6). It must be seen in complete darkness to have the glow apparent. This weak light comes from the entire peripheral cytoplasm and by some it is thought that it originates in the yolk material. It is more probable that it comes from tiny granules of photogenin in the cytoplasm between the larger yolk granules.

FIG. 6.



Egg of *Photuris]pennsylvanica.* The facets correspond with the yolk granules inside. (After F. X. Williams.)

No further observations have been made on the light until the embryo is well developed and is almost ready to hatch. Then the light is seen to come from two distinct points and these points are readily recognizable as the typical light organs of the larva as seen in all forms without exception.

These organs are two latero-ventral, rounded spots on the eighth abdominal segment. They are applied closely to the hypodermis which covers them and bulge outward as two knobs or sometimes two weaker lens-shaped prominences. Fig. 4 shows their position. The light organs of the larva never flash or sparkle, but, when in action, shine with a steady glow. Much of the time no light at all comes from them and they do not glow when the larva is resting or hibernating beneath the dead leaves on the ground.

The light is brought into action whenever the animal is disturbed or roughly handled. Then the glow slowly appears, and attains its maximum in a few seconds. It will continue as long as the stimulus is applied and afterward it gets weaker and weaker until, in a minute or more, it has entirely disappeared.

On a damp night, when the creatures are out hunting their prey, they have the habit of turning the light on and allowing it to glow for considerable periods, for minutes at a time. Then, for no known reason, the light will die out, to reappear again later. This is particularly true of large larvæ in the grass, late in the fall on cool nights, when they can be seen for several hundred feet away.

The larvæ usually occupy well-defined areas or colonies where the adults, later, will fly during the mating season. They can best be seen and caught on dark nights after or during a drizzling rain.

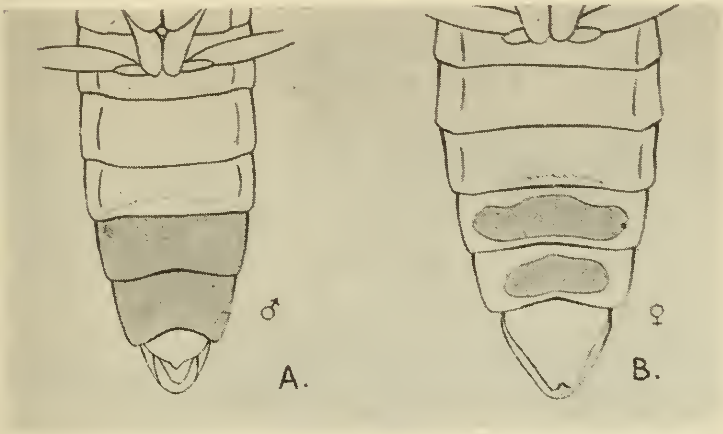
The larva keeps its light, up to and during the torpid condition that occurs after it has built the nest in which it pupates. Even when in this helpless condition it responds to handling or shaking by turning on its lights. After the skin is shed and it has become a pupa these two larval lights still shine until shortly after the time when the adult light is developed. They then disintegrate and disappear in most of the species, although retained in some.

The adult light organs appear during the pupal condition, first as patches of lighter integument, later as white areas that can shine. They do not light all over the surface of these areas at once, but show streaks of light and smaller patches, usually near the middle or posterior edge. Just before hatching they light up all over but do not flash, slowly lighting and slowly darkening, much as the larval organs do.

These adult organs show considerable variation both in number and in the different species; also some difference in the two sexes of a number of the species. The commonest and most ample arrangement appears to be an organ covering most of or the entire ventral surfaces of the sixth and seventh abdominal segments, as seen in the male of *Photuris pennsylvanica* (see Fig.

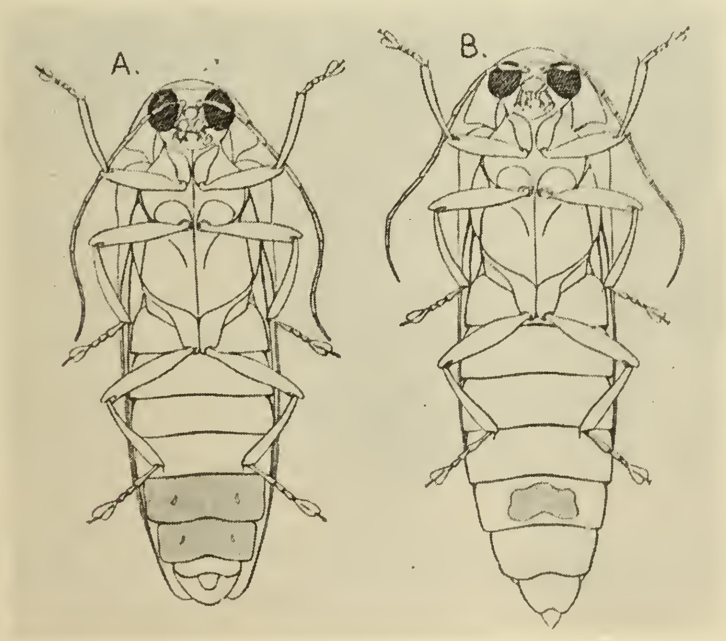
7, A). In fact, this consists of two organs, one occupying each of these two segments. In the female the organ is usually found to be in a similar position but restricted to a more or less smaller and central portion of the two segments. This is shown in the female of *Photuris pennsylvanica* (see Fig. 7, B). In some other

FIG. 7.



Sketch of the ventral aspect of the abdomen of the male (A) and female (B) of *Photuris pennsylvanica* to show position and size of light organs. The stippled areas represent the light organs. (After F. X. Williams.)

FIG. 8.

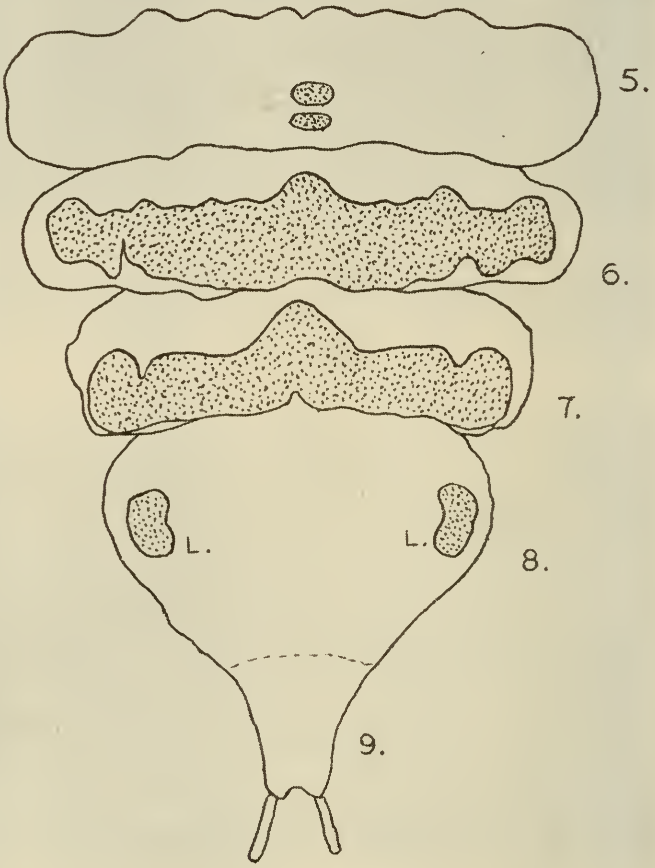


Sketch of the ventral aspect of *Photinus consanguineus* to show position and size of light organs. A, male. B, female. The stippled areas represent the light organs. (After Watase.)

species the female has the organ on but one of these segments, when it is the most anterior of the two, or the sixth. We can see this in the female of *Photinus consanguineus* in Fig. 8, B.

In certain forms the female has median light organs on more than two segments, as in *Lampyris noctiluca,* where they appear

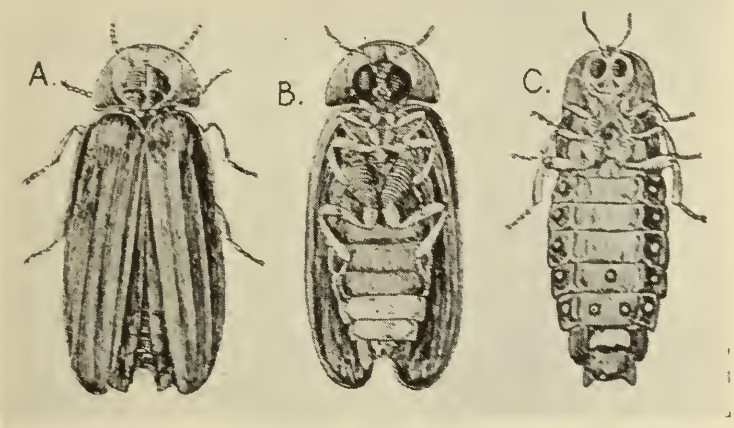
FIG. 9.



Sketch of the ventral aspect of a female of *Lampyris noctiluca* to show the number, position and extent of the light organs. Stippled areas represent light organs. L, larval light organs on eighth segment. (After Geipel.)

on the fifth, sixth and seventh, while the larval organs persist on the eighth (see Fig. 9). A still more extensive development appears in *Lampyris splendidula,* where the male has large median organs on the sixth and seventh (Fig. 10, B), while the female shows one small median organ on the fourth or fifth (with some variation), two small lateral organs on the sixth, one large median organ on the seventh and five medium-sized light organs on each edge of the abdomen on the second, third, fourth, fifth and sixth (Fig. 10, C). This female is half-winged or almost wingless, white or light cream-colored in hue, and lies prone on the ground, shining brightly, much brighter than most other forms, while waiting for her mate. The light is constant like the glow-worm's (larvæ) and does not come in flashes as in most adult forms. The writer has collected many of these illuminated females on the edges of forests on the mountain side near Neustadt a/d Hardt, in Southern Germany.

FIG. 10.



Three views of the fire-fly, *Lampyris splendidula*. A, dorsal view of male. B, ventral view of male. C, ventral view of female to show the numerous and widely distributed light organs. (After Flöricke from Mangold.)

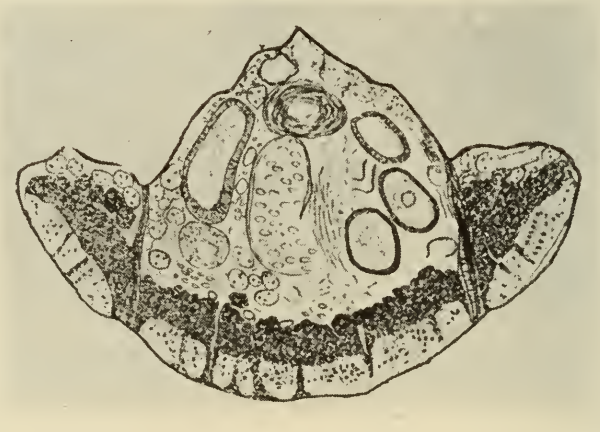
A general survey of the question of the position of light organs in the Lampyridæ shows that they vary greatly in number and position, and yet certain general principles can be laid down which seem to govern their arrangement. The first idea is that they incline to be placed on the posterior portion of the abdomen and that they are ventral in position. This accords with the general law that practically all luminous organs in the various groups of animals are ventral in position and show their light downward.

The next apparent rule is that the lights are bilateral in their more primitive manifestation, as in the larvæ, and in those cases when they are found in larger numbers, especially in the cephalic direction. The median lights must all be looked upon as a fusion of bilateral pairs and as a more specialized condition of the organs. Thus, the extreme caudal organs in adult fire-flies are usually larger and fused into such a single median mass, while in those that appear cephalad of the sixth and seventh segments they are almost always smaller and widely separated on the lateral sides of the segment. This holds true in all Lampyrids as well as in the allied *Phengodes*.

STRUCTURE OF THE ORGANS.

All the organs, both larval and adult, agree in some general features. They each consist of two fleshy layers of cells attached to the integument (hypodermis and cuticle), which becomes, over the area involved, perfectly transparent, thus permitting the color of the layers to be seen. Fig. 11 shows these two layers in a section of the body.

FIG: 11.



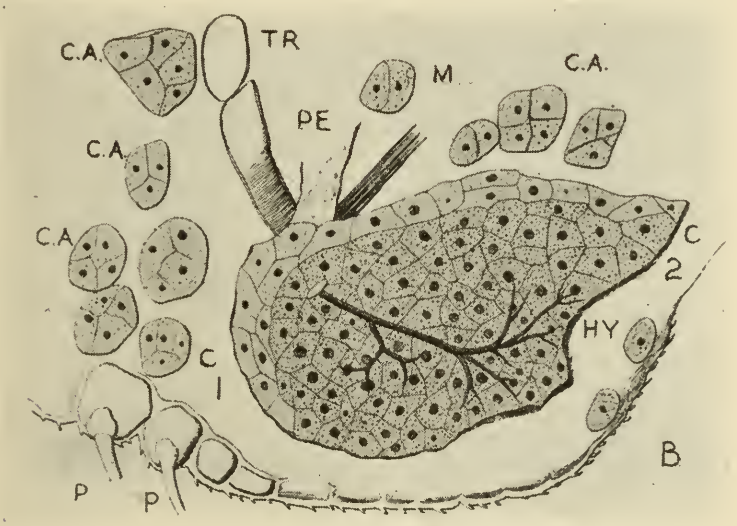
Low-power view of a transverse section of the body of an adult fire-fly through the light organ. (After Townsend.)

The layer next to the integument, commonly the ventral layer, since the organ is usually on the ventral surface, is the layer of light cells and it is a transparent yellow in color. A pale yellow color appears to be typical of most protoplasm, but a somewhat richer yellow also appears to be characteristic of photogenin in the few cases in which we have been able to see it, either in isolation as in *Cypridina* and *Cavernularia*, or still mixed with the nuclei and cytoplasm of its parent cells as in some squids, certain fishes and the fire-fly.

The second layer is further inside and is therefore dorsal in position to the first. It approximates the light layer in thickness and is composed of cells of nearly the same size. These cells, as in *Pyrophorus* (see Chapter 10), contain in their cytoplasm a mass of granules of calcium urate and their bodies act as a reflector of light, thus performing two duties: they prevent the light that is generated in the light cells from being thrown into the delicate internal tissues of the body and they also throw back these light rays that start dorsally or inward and add them to the rays that have started outward, thus nearly doubling the illuminating powers of the organ.

When we come to study the structure in further detail we find that certain differences, of degree mostly, make it desirable to examine the organs of the larva first. Fig. 12 is a representation of part of a transverse section through the eighth abdominal segment of a larva of *Lampyris noctiluca* and shows this organ *in situ*. Here it can be seen that the light cells or ventral layer form a thick rounded mass and are, in nature, almost in contact with the hypodermis and cuticle. In the figure they are some distance from it, due probably to osmotic action of the fixing and embedding processes. These light cells are packed closely together in the mass and show no morphological arrangement other than the rounded shape of the mass.

FIG. 12.

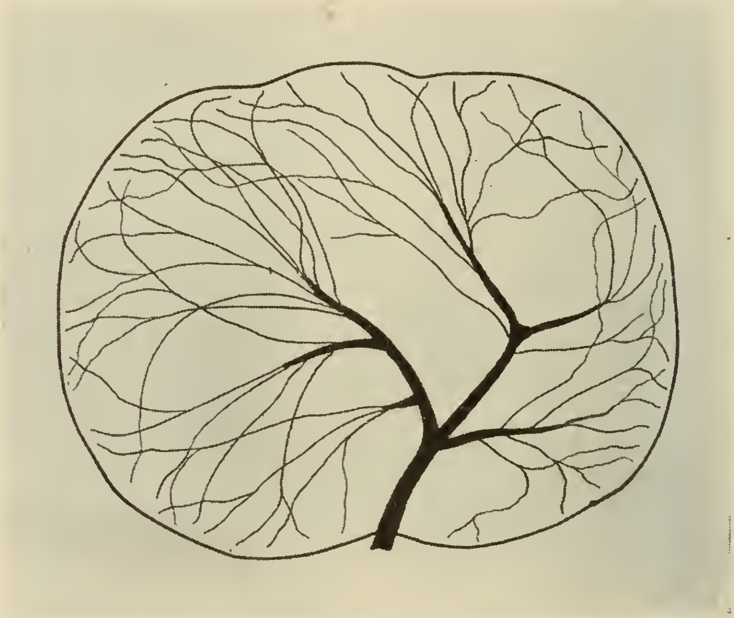


Low-power view of part of a transverse section through the body of a larva of *Lampyris noctiluca* to show a section of the larval light organ. The ventral mass of darker cells with a trachea branching among them are the light cells. The lighter, thinner mass of light-colored cells are the reflector cells. (After Henneguy.)

Each cell is robust with a large nucleus and large cytoplasmic body which would not be so large and dense if it were not active in some secretory process. The granules that fill it are proof of such an activity and they are granules of photogenin, small rounded granules that fill the cytoplasm in all parts. No portion is free from them.

We see no evidence of a blood supply, although one may be present. Or the cells may pass the necessary substances from one to the other. As to the air supply, it can easily be seen in the figure that this is abundant and consists of tracheal twigs, as represented by a single branching twig in this case. It arises, out of the section, from one of the larger branches such as is shown above the organ in the figure.

FIG. 13.



Drawing of a single larval light organ of *Lampyris noctiluca*, treated with caustic potash to render the tissues transparent and bring out the tracheal system, here seen black. (After Geipel.)

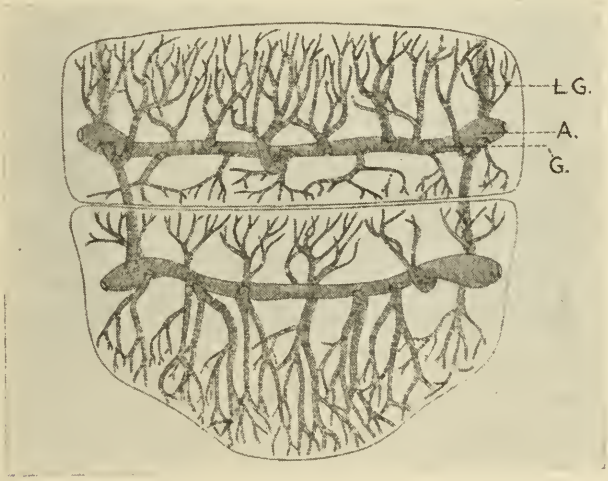
The structure of the terminal parts of this branching twig has been carefully studied in the adult by Bongardt, Geipel, Emery, Lund, Vogel, Shultze, Townsend and many others. Its appearance in the *larval* organ has best been demonstrated by Bongardt. In Fig. 12 Henneguy shows a single trachea entering the organ and branching in the light-cell mass. Fig. 13, from Bongardt, shows a preparation made transparent by caustic potash and showing the finer branches of this single trachea which supplies the layer. Tracheal end-cells seem to be wanting in this larval organ.

Outside of and dorsal to the light-cell mass are seen the layer of dorsal reflector cells. This layer is thin in the larval organ and yet it forms a complete and efficient reflector. The individual cells will not be described because they are apparently exactly like the reflector cells as seen in the adult.

THE LIGHT ORGANS AS FOUND IN THE ADULT.

The adult light organ is not the same as, nor is it directly derived from, the larval organ. Its relations and method of development will be discussed in some following pages devoted to the subject.

FIG. 14.



View from ventral side of a diagram of the arrangement of tracheæ that supply the two light organs in the male of *Luciola africana*. (After Geipel.)

As has been said, it consists of one or more areas on the ventral side of the abdomen, usually two large portions of the sixth and seventh segments. Thus it is multiple, but all of the portions are alike in structure, consisting of ventral light-cell layer and a dorsal reflector layer. Fig. 11 shows these layers in a section of the body of the adult insect.

The organ has a very large air supply coming from specialized tracheæ that are found in the tissues immediately above it. Geipel shows that in *Luciola africana,* a main trunk (A), formed by the anastomosis of the trachea from each side of the segment, forms the basis of this supply in each segment and that the air is conducted down to the organ from this large tube by about fifteen side branches (Fig. 14), which in turn divide into the unit trachea of the organs.

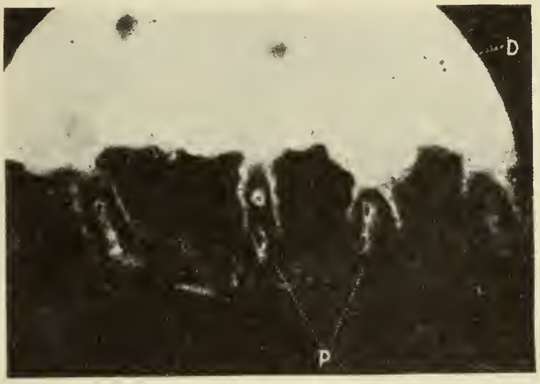
The reflector layer is composed of a solid mass of large cells that resemble greatly those of *Pyrophorus*. They have a nucleus typical of the insect and a large cytoplasmic body in which are secreted and stored a great mass of bodies of calcium urate which completely fills the cell outside of the nucleus. Geipel has compared the size of nucleus and cell in this layer with the cells of the underlying light layer in some African Lampyrids and finds that, while the light cells in these Lampyrids average 0.0304 mm. in diameter and the reflector cells 0.0272 mm., which is a small difference, the nuclei of the light cells average 0.0064 mm. and those of the reflector cells 0.0112.

The writer has made similar comparisons in several North American forms and two Japanese forms and has noted the figures of several species in papers by Lund, Bongardt and others, and finds that such large differences do not exist in these forms. In general the nuclei are much alike in size and form in both layers. This form is sometimes round, but more often they are irregularly rounded or even lobed and with blunt processes.

The question has been raised by Lund and others as to the origin of the urates that are found in the reflector cells. Is it possible that the waste products of metabolism in the light cells and muscle cells are used to fill these units with this material? Some have even suggested that these dorsal light cells are transformed into reflector cells by filling them with the urates from the light processes in the cells below them and that the animal begins life with a thin reflector layer and a thick light layer and that as the light is used and the creature grows older the reflector layer thus grows thicker at the expense of the light layer. Most of them have answered this in the negative for two reasons: First, the two layers remain about constant in their relative sizes at all ages. This relation is about half and half in *Luciola parva* and *Luciola vitticollis* from Japan. The same holds true for *Photinus marginellatus* and in *Photuris pennsylvanica*. In some others, however, as the fire-flies from Africa, Italy and Northern Europe, Geipel found that the reflector layer occupied one-third of the thickness of the organ and the light layer two-thirds. In one case, a section drawn by Townsend from an unnamed species shows the reflector layer thicker than the ventral layer.

The second reason for deciding that the dorsal or reflector layer does not grow at the expense of the ventral or light layer is that no cells have ever been observed in any stages of transition. Such a transformation would be easily discernible, as the cells of each layer stain in very markedly different ways. To sum up, it is probable that the reflector cells have the specific power of secreting the urates and maintaining them in their cytoplasm in a form well adapted for reflecting light; also, that they possess this power from the very first and that no cells from other tissues are ever added to this layer. Fig. 14 is a photograph of the fresh-cut body of *Photuris pennsylvanica,* showing the deposits of urates by reflected light. It can be seen that they are not confined to the reflector cells alone but are also found in small quantities in the luminous cell edges, around the nuclei and in some of the visceral tissues.

FIG. 15.

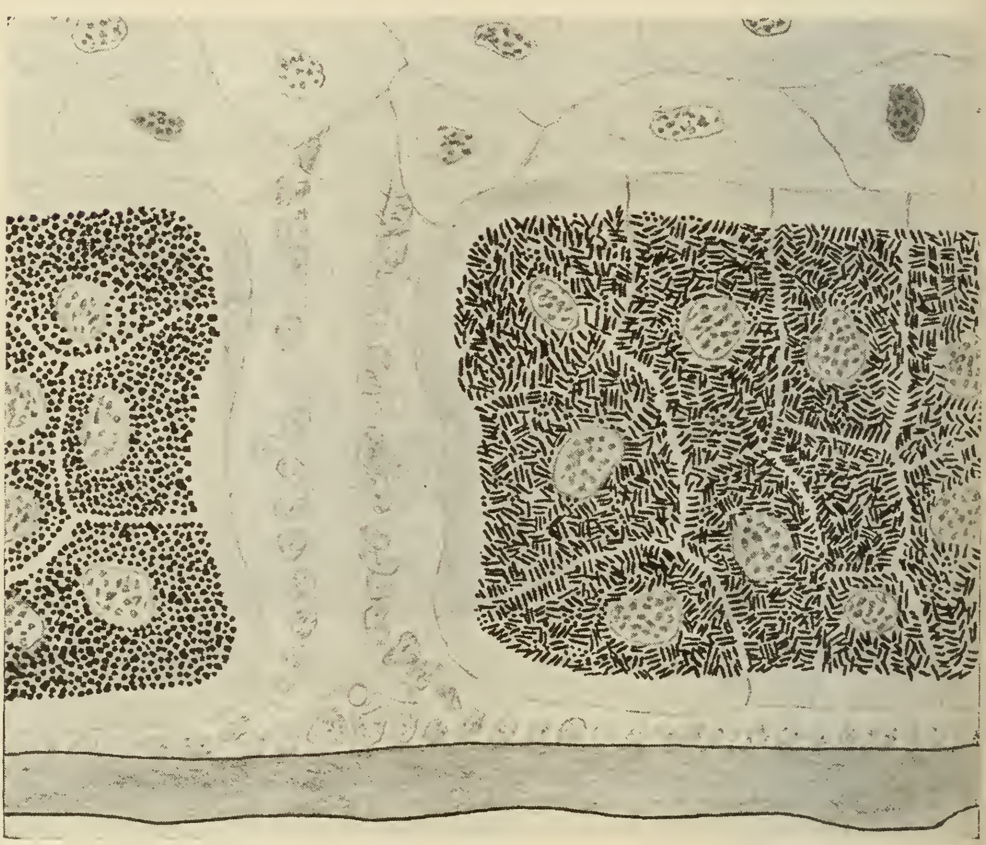


Photograph of the transversely cut end of the seventh abdominal segment of *Photuris pennsylvanica.* Light areas represent urates in reflector shining by the light of a bull's-eye lantern placed behind the camera. (After Lund.)

The reflector cells form a compact mass, but tracheæ as well as nerves are found branching among them. The nerves probably go on through to supply some of the light tissues, and most of the trachæ do the same. But some small tracheal branches end in the reflector layer, and this ending is by means of the much-discussed "end-cells."

Passing now to the ventral layer or light-cell layer, we find that it is made up mostly of these light cells. Each cell is provided with a large nucleus as described, and its large cytoplasmic body is filled with the secreted photogenin or luciferine. This material appears in the form of granules which are small but of a definite shape. In *Photinus marginellus,* for instance, they appear as small round bodies in the male. But in the female they are elongate bodies of larger size. In the first they closely resemble cocci and in the second rod-shaped forms like bacteria.

FIG. 16.

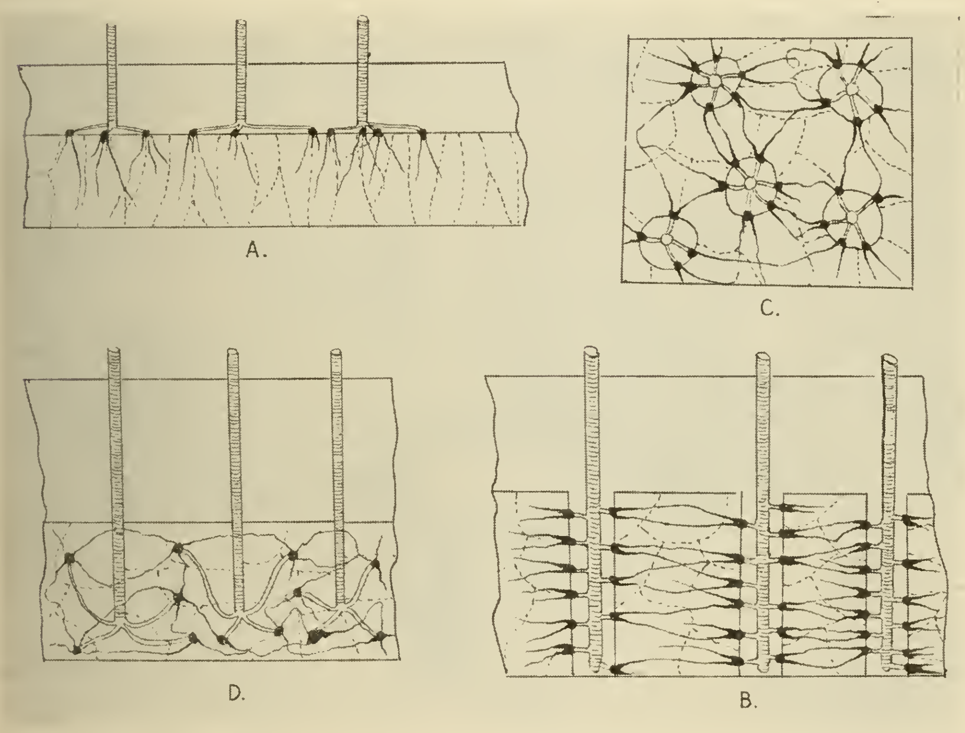


Part of a vertical section through a light organ of *Photinus marginellus*, showing one cylinder with its tracheal unit and accompanying tissues poorly stained; also, at top, parts of nine reflector cells, also poorly stained. This figure is intended to show to best advantage the light cells, two masses of which appear. In the mass to the right the female type of photogenin granules is depicted. In the mass of light cells to the left the male type appears. The oxygen protecting membrane or ectosarc of the light cells is well shown. (Original drawing.)

In fact, they were taken to be bacteria by Pierantoni, who ascribed the light of fire-flies to bacteria living symbotically in the tissues of the light organ and even thought that he could cultivate them on artificial media. His cultures must have become inoculated by outside bacteria from air, water or other sources.

The staining of the photogenin granules was a matter of guesswork for some time to the writer. They are very hard to stain in ordinary fixations, coming out untinged in many good stains. Osmic acid only slightly stains them. Finally it was discovered that all that was necessary was to see that the fixative was heated nearly to the boiling point, no matter what fixative was used. At least this was true of Flemming's fluid, Bouin's fluid and corrosive sublimate and acetic acid. Then iron hæmatoxylin brought them out clean and blue-black on a light ground. Fig. 16 shows them in male and female in *Photinus marginellus*.

FIG. 17.



Four diagrams to illustrate the three known types of fire-fly light organs. For explanation see text.

In some of the fire-flies (*Photinus marginellus*) the granules of photogenin do not fill the entire cytoplasmic body. In this case, as is shown in Fig. 16, there is a peripheral zone which is free from them. This zone does not exist where one light cell touches another. Lund figures and describes this zone but is at a loss to account for its function. He saw that it was dense and stained differently from the rest of the cytoplasm.

In the writer's opinion this membrane-like zone, common to the entire exterior of any mass of the light cells but not existing where their surfaces touch each other, is a defence against the entrance of any oxygen that might come into the cells except through the tracheal capillaries. What may happen, one may ask, in the forms where such a membrane does not appear? Its place may be taken in these cases by a thinner layer or a better general resistance of the cytoplasm or the cell membrane to the access of oxygen.

The arrangement of these light cells in the various forms, while seemingly different in many of the species, has a common plan with reference to their access to the supply of tubes bearing the oxygen. In some forms of *Photuris* the cells form what is practically a single layer. In this case the unit branches of tracheal supply come down through the reflector layer at well distributed points and branch out into tracheal twigs that spread in several directions over the upper surface of the light layer and terminate in tracheal end-cells, from which the tracheal capillaries branch and penetrate the mass of light cells. Fig. 17, A, is a diagram illustrating this relation.

FIG. 18.

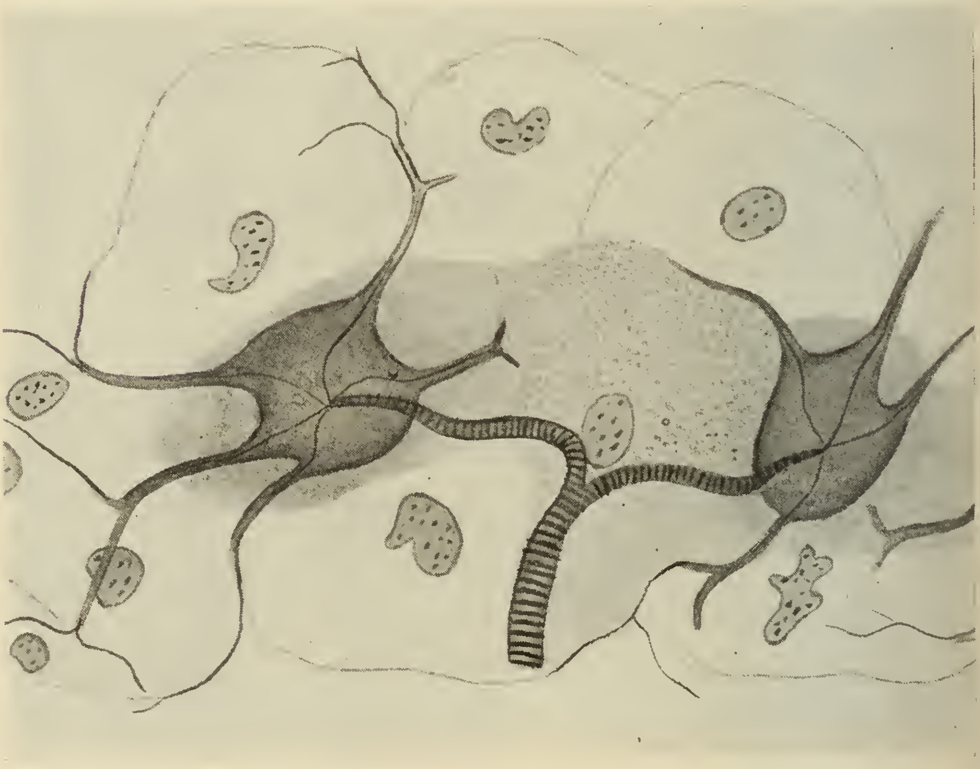


Figure of a portion of light tissue from *Lampyris splendidula* to show effect of breathing osmium vapor on the cytoplasm of the end-cells and surrounding tissues. (After Bongardt.)

The second type of adult Lampyrid organ is where the light layer is composed of several thicknesses of cells. In this type we find two subtypes. First comes the condition found in our American species of *Photuris* and *Photinus*. Here the tracheal unit branches enter the light layer through a well or circular hole in the mass of light cells. The trachea and its accompanying tracheal epithelium and tracheal end-cells fill this well from top to bottom and form a mass of tissue called from its shape "the cylinder." These cylinders are spaced through the layer in such a way that the air supply is kept within a certain distance of all light cells. Fig. 17, B, will show a diagram of this arrangement seen in vertical section, while C in the same figure will show a diagram of the arrangement as seen in a horizontal section cutting across the cylinders.

This arrangement is like the first type (A) in that the tracheal units do not actually enter the light cells and that the tracheal end-cells rest on the surface of the light-cell mass either on its actual upper surface between the cylinders or on the inner side of the cylinders. Thus, in regard to its actual physiological opportunities, it is in reality only an amplification of the first type. On the other hand, the tracheal units do actually leave the reflector layer when they pass down into the cylinders.

The second subtype of this group is found in several far eastern forms and can be well seen in *Luciola parva* and *Luciola vitticollis* from Japan. In this kind the light-cell mass is not amplified by the invaginated cylinders, but forms a smooth, compact mass of several layers of cells in depth. The tracheal units come down through the reflector layer and enter the light-cell layer without any accompanying invagination of that layer into "cylinders." The units, after penetrating half way, more or less, branch into the terminal twigs and these scatter about for a short distance and terminate in the end-cells, from which they branch out into tracheal capillaries. Fig. 17, D, shows a diagram of this condition.

AIR SUPPLY.

We have seen that, since the oxygen supply of insects is not carried by the blood, but by a system of air tubes, the various tissues of insects are dependent for their air with its supply of oxygen upon a system of branching of these tubes called the trachea. As has already been shown (Fig. 14), each adult light organ in the fire-flies is supplied by two large tracheal trunks that meet and anastomose from the two sides of the segment and give off in their length about fifteen secondary branches that we have called the "tracheal units."

These tracheal units then approach the light-cell mass and either deploy on its upper surface or enter the cylinders or pass directly into and between its cells. Finally they give off a large number of "terminal twigs," each of which terminates in an "end-cell." Up to this point all the tracheal channels, trunks, tracheal units and terminal twigs are of the same structure. They are formed by a membrane composed of the tracheal epithelial cells, which are an invaginated contamination of the external hypodermal cells, and the actual wall of the circular tracheal channel is a continuation of the external cuticle, much reduced in thickness. Owing to this thinness and necessary delicacy, the wall of the tracheal channel has to be reinforced by a series of circular or spiral ridges called the tænidia. At the distal tip of each terminal twig one of the cells of the tracheal epithelium becomes much enlarged and its distal end is prolonged into several (2 to 7 or more) fine protoplasmic branches which become more slender as they reach out and branch between or through the tissue cells that are to be supplied with air. This cell and its branches then continue the formation of cuticle in the form of fine tracheal capillaries or tracheoles that extend out in the distal arms of the end-cell as far as they continue. Such end-cells are found in most other insect tissues as well as in light tissues.

It is in and through these tracheal capillaries or tracheoles that the physiological exchanges of the light cells take place. This has been abundantly proved by the experiments of Emery, Wieliwiejski, Bongardt, Lund, Geipel and others. This proof consists in forcing the living insect to breathe the strong vapor of osmic acid and then noting, in subsequent preparations, where air bearing this osmic vapor has passed most freely through the tracheal channels and stained the surrounding cells.

The results have shown that, while some osmic vapor has gotten through the larger channels, the greatest effect takes place in the distal part of the end-cells and in the tracheal capillaries. Fig. 18 shows this abundantly.

Another question is, as to whether the tracheal capillaries anastomose or not with the capillaries from other unit trachea. These capillaries are very fine and hard to follow, but the weight of evidence seems to show that some if not all of them do. Townsend figures this anastomosis, and, as Lund says, such an anastomosis might contribute to the flow of air through the capillaries. This would be especially true if the air pressure was slightly different in two tracheal units whose capillaries were in connection.

FIG. 19.

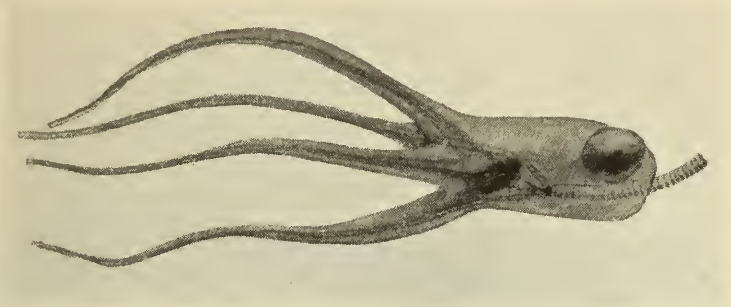
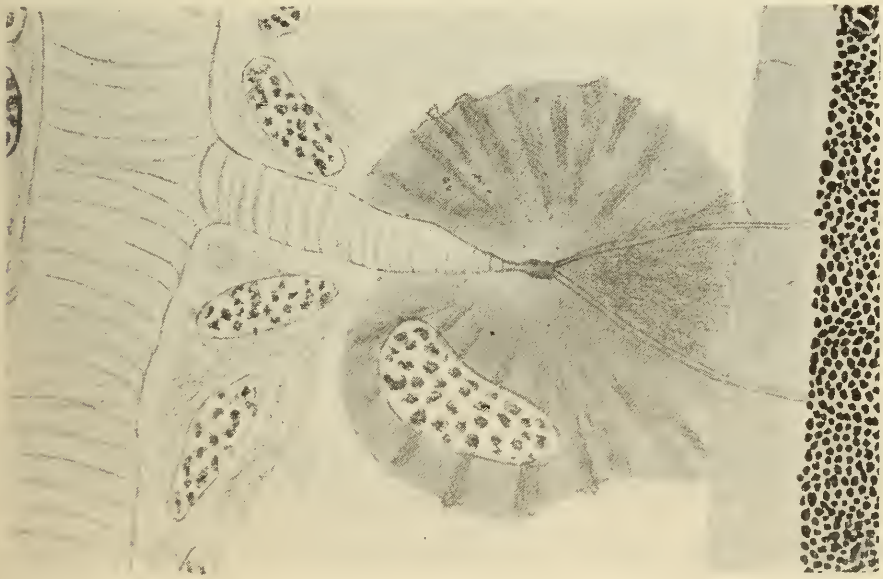


Figure of a tracheal end-cell from *Photinus marginellatus*. (After Geipel.) This figure shows the nucleus terminal twig and capillaries, but does not show all the cytoplasm of the cell. This latter forms a larger and more rounded body in addition to the mass seen here. It also has a radial arrangement of its protoplasm.

FIG. 20.

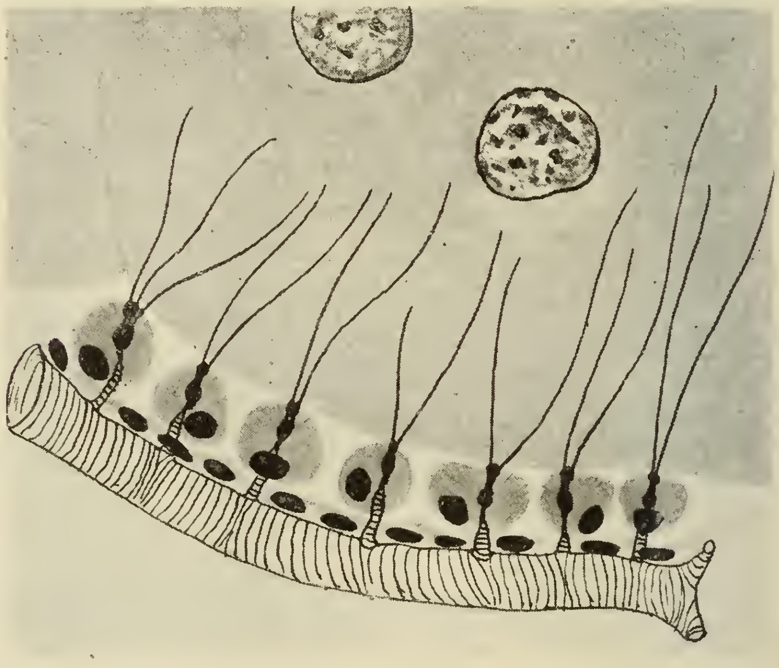


View of a tracheal end-cell from *Photinus marginellus*. Fixed in hot Bouin's fluid. Tracheal unit is seen giving off a terminal twig, which terminates in the end-cell. Origin of two capillaries is seen, also radial arrangement of cytoplasm (probably muscular). The denser mass of cytoplasm between the tracheoles and against the light cell is probably the secondary mass that is stained black in the next section. (Original drawing.)

Another interesting question is whether the capillaries are filled with air or body fluid during life. The probabilities are that they do contain air but that upon the least injury, mechanical or pathological, the body fluids invade their lumen and slowly fill the first and then fill the terminal twigs. Quick dissections of the tissues have shown the fluid slowly creeping through the tracheal capillaries and up into the terminal twigs.

The function of the end-cells is not fully understood. Whether they only form and maintain the capillaries or whether, in addition, they exert some control over the flow of air has often been debated. The terminal twig may be plainly seen as it enters the end-cell (Figs. 19, 20, and 21). Inside this cell the large round nucleus is visible, usually to one side, and about in the middle the twig suddenly loses its tænidia and shows a strong, dark-staining sheath that forms a distinct body (see same figures). This body is smaller than the twig in some forms and slightly larger in others. It ends in a point in either case, and from this point the tracheal capillaries, or "tracheoles," as they are called by some

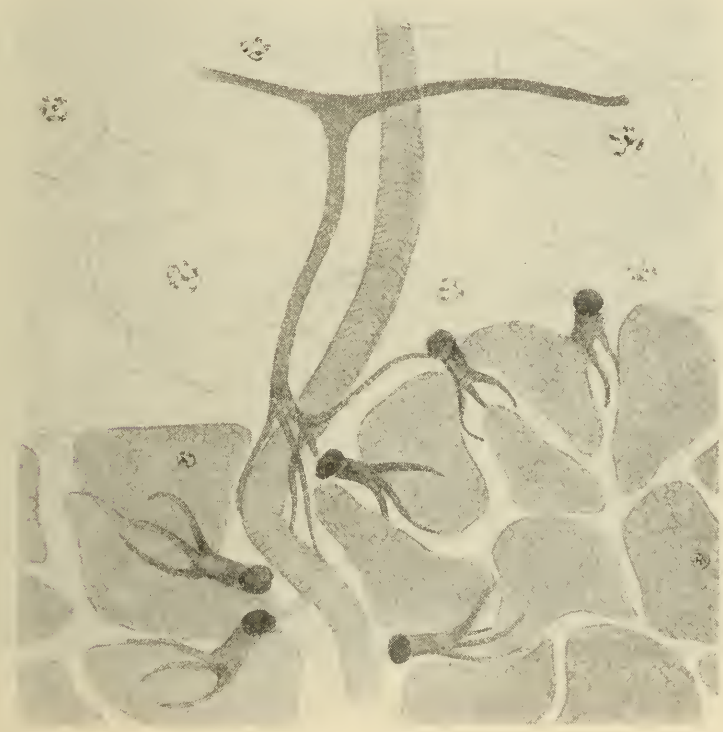
FIG. 21.



Seven tracheal end-cells with their tracheoles entering the light-cell mass of *Photinus marginellus*. With this fixation and stain all nuclei and much chiten is stained black. Also a distal secondary mass of tissue around the tracheoles stains black. The photogenin granules show no trace of stain. Fixed in cold sublimate-acetic acid and stained with iron hæmatoxylin.

are given forth. This specialized body forming the end of the terminal twig inside the cell is not readily seen in osmic preparations on account of the darkening of the surrounding cytoplasm; but in sublimate preparations stained with osmic acid it becomes visible, and it stains darker than the other portions of the larger tracheal channels. Sometimes it also stains darker than the capillaries that it gives off (Fig. 21).

FIG. 22.

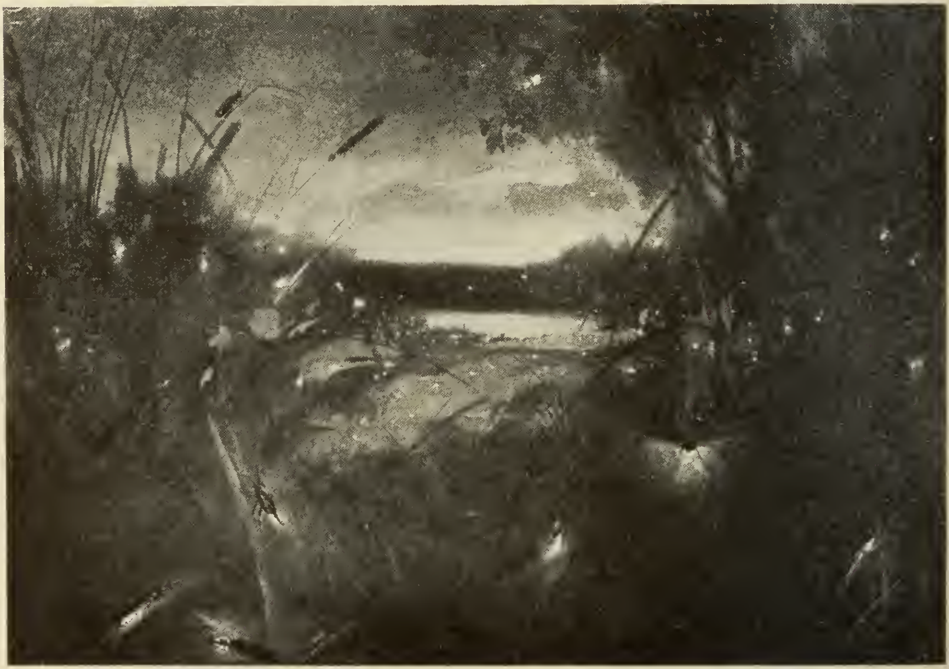


Showing six end-cells in the light tissue of *Photinus marginellatus* from South America. A tracheal unit sends off air supply to the light cells through the terminal twigs and tracheal end-cells; while a nerve stem sends fine nerves to the end-cells for their control. (After Geipel.)

This standing reaction may point to a contractile layer of cytoplasm surrounding it, with the possibility of a valve, in addition, in its lumen. Also the larger body of cytoplasm surrounding it sometimes shows a radial structure that may point to a general contractile power (Fig. 20). Further evidence that this cell in some way controls the passage of air into the tracheoles is shown by the fact that the nerve supply sends a minute fibre to each of these end-cells. Geipel shows this, although he does not show the definite nerve ending on each cell (Fig. 22).

Such a control of the air supply by the end-cell with its muscular power and an adequate nerve supply would account for the control of the flash of light of the fire-fly. This light is emitted in short, sharp flashes, although sometimes, when injured, fatigued, or excited, or subjected to chemicals or near death, it also shows a steady glow. It has been shown by experiment that the light is controlled by the nervous system in *Pyrophorus* and the necessary nerve supply exists for this control in the Lampyrids. The control of the light has even been shown indirectly in these latter forms. It must have a reflex centre in connection with the sex centres, and the glow in injury and other unusual conditions show that its control is probably of an inhibitory nature, with the end-cells as the seat of the direct action.

FIG. 23.



View of fire-flies, *Photuris* and *Photinus*, during their evening flight in early summer. (Drawing by Bruce Horsfall.)

A following chapter will deal with the development and larval transformation of the light organs of Lampyrids and the physiology of the processes in these forms.

(*To be continued.*)

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

A SPECIFIC GRAVITY BALANCE FOR GASES.[1]

By Junius David Edwards.

[ABSTRACT.]

THE need for an accurate method of determining gas densities has been especially urgent in the natural gas industry where the measurement of gas by means of orifice meters requires a knowledge of the density of the gas. An investigation by this Bureau of the effusion type of apparatus, which has been generally used for this purpose, but which has proven unreliable in practice, has shown the need of more precise methods. To supply this need the present method was adopted and suitable apparatus designed.

The principle of the method employed is based upon the laws of the compressibility (Boyle's law) and the buoyant effect of gas. The balance contains a beam which carries on one end a relatively large globe and on the other a small counterweight; the beam is enclosed in a gas tight chamber. The buoyant force exerted upon the globe is proportional to the density of the gas and therefore to its pressure. Therefore, if the buoyant force exerted upon the globe is made the same as shown by its position of equilibrium when it is suspended successively in two different gases, then the densities of the two gases must be the same at these pressures, or the specific gravity is the inverse ratio of the pressures.

In operation the balance case is filled with air and the pressure adjusted until the beam balances. It is then filled with gas and the pressure required to secure a balance is determined in the same way.

The apparatus described provides a quick, accurate means of determining gas density. The balance beam is supported on two needle points which give high sensibility. The needles are easily adjustable and in contrast with the metal or quartz knife edge usually used, can be obtained almost anywhere, are inexpensive,

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* Communicated by the Director.

[1] Technologic Paper No. 89.

and can be replaced as often as necessary. The success obtained in the use of this apparatus is mainly due to the high sensibility afforded by this means of support. It is necessary to remove the beam from the case only when it is desired to transport it. No levelling bottle is necessary in adjusting the gas pressure within the balance, this being accomplished by means of a needle valve which affords precise control. A portable outfit is described which combines lightness of weight, convenience in use, and durability without any great sacrifice of accuracy. No preliminary calibration of the apparatus is necessary. The results obtained with this balance were compared with those obtained by a direct weighing method and it was shown that an accuracy of 1 or 2 parts per 1000 could be obtained quickly and without elaborate precautions.

THE STRUCTURE OF THE COATING ON TINNED SHEET COPPER IN RELATION TO A CURIOUS CASE OF CORROSION OF THIS MATERIAL.*

By Paul D. Merica.

[ABSTRACT.]

THE attention of the author has been directed to a curious and instructive case of local corrosion or pitting in tinned sheet copper roofing. The pits occur in general along the line of surface scratches, having appeared some 8 or 10 years after completion of the roof. These pits are apparently unrelated to the service conditions, and to the direction of rolling of the sheet.

A study of the structure of tin coatings on copper has been made, and has shown that this coating consists of at least 3 layers, viz., a thin layer of Cu_3Sn immediately next to the copper, then a layer of Heycock and Neville's constituent H, containing about 60 per cent. by weight of tin, and finally, a layer of the eutectic of tin and copper, in which is found most probably also the lead when it is present in the tinning mixture. This coating in the case of the corroded sheet was thin, averaging about 0.012 mm. in thickness, and quite variable in both thickness and struc-

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* Technologic Paper No. 90. A copy of this paper may be obtained by application to the Bureau of Standards, Washington, D. C.

ture, varying from 0.006 mm. to 0.03 mm. in thickness. At many points there were breaks in the continuity of the alloy layer; at others, breaks in the continuity of the eutectic layer.

Etching experiments and measurements of electrolytic EMF of these layers toward various solutions, such as water, dilute acids, and acids to which ferric or stannous chlorides had been added, showed that the constituents of these intermediate alloy layers are more electronegative, *i.e.*, less corrodible, than either the tin or the copper. Values were found for the EMF of these alloy constituents against copper in various solutions varying from −5 to −80 millivolts.

When the copper becomes exposed, therefore, as in the present case at the bottom of the scratches on the surface, it forms together with the alloy layer a galvanic couple, electrolytic action sets in, and the copper at these points is corroded, forming the pits described.

Many instances are known, of course, of roofs of such material, which have been in service for 20 and more years, under severer conditions, as regards smoke, soot, etc., etc., than were those under which the roofing in question failed, and which nevertheless have not shown sign of such pitting. Explanation of this variation in service rendered by different samples of the same type of roofing material must be sought in the variation of mechanical abuse, such as scratching, which it receives, and also in the uniformity of structure and thickness of the tin coating.

Stellite vs. High-speed Steel. R. SYLVANY AND H. HAEFFELY. (*La Chronique Industrielle*, vol. 39, No. 279, p. 6, December 28, 1917.)—According to an account given in *Metaux et Alliages*, the hard non-ferrous alloy, stellite, invented three or four years ago in the United States by Elwood Haynes, marks a still greater advance in the art of cutting metals than established by the notable results obtained with the introduction of high-speed steel some years earlier. Where rate of production is a critical matter, as in the manufacture of ammunition, it has already made a remarkable record in competition with high-speed steel, a material which in point of capacity of production outclassed steels previously used. One of the advantages of stellite is that its hardness, which it maintains even at a red heat, is solely dependent upon the composition of the alloy, tungsten and chromium with additions of cobalt and molybdenum, and not upon the difficult and uncertain operations of heat treatment. Its fundamental advantage, however, lies in its ability to withstand a marked increase in speeds and feeds over those previously used with high-speed steels.

Among the already numerous machine shops employing stellite, the Fonderie des Gobelins in Paris reports that a daily production with high-speed steel of 120 shells of 155 mm. was increased to 200 by the use of stellite. With high-speed steel 21 minutes were consumed in roughing out at a speed of 17 meters and a feed of 0.7 mm. For finishing, the same speed and feed were employed and the same time was consumed. With stellite the roughing-out occupied 11 minutes at a speed of 25 meters and a feed of 0.85 mm. For finishing a speed of 37 meters was maintained with a feed of 1.67 mm. consuming 4 minutes. For completely finishing 1000 shells of 155 mm., the cost of stellite is about 0.30 francs per shell. Other firms report equally favorable results in this class of work.

Sub-aqueous Mining of Anthracite Coal. P. A. ROCHE. (*Scientific American*, vol. cxvi, No. 4, p. 98, January 27, 1917.)—Present day conditions as to the utilization of anthracite coal are now so acute that we find in actual operation plants to recover from river beds by sub-aqueous mining the fuel that for nearly three generations has been buried under water in many of the streams that flow through the extensive anthracite coal regions. The smooth surfaces worn by attrition, it is true, have not the glitter of the freshly mined "black diamond," but the combustion value is in nowise impaired, for it happens that the product is the best coal of the mines. These deposits of coal, found in deep layers just above dams, and in pockets where small river whirlpools existed, are easily reached; and the centrifugal pump, traveling bucket conveyor, and even the Archimedes screw are now winning between half a million and a million tons yearly of this previously ignored valuable material.

In the Schuylkill region a move was initiated towards a systematic modern handling of coal laden river bottoms, and it may be remarked that the past half dozen years has seen a great increase in the number of dredging plants throughout the anthracite coal country. No land need be purchased as for surface mining; no driving of shafts, etc., and in many cases no payment of royalties: an investment of $2000 in a pumping plant, second hand canal boats and like equipment, and the river operator is equipped for work. At the most liberal estimate the cost of getting the coal out of the water is 12 cents per ton. The price paid by one consumer who uses nearly the whole output of two of these plants, each consisting of one battery of pumps, is $1.35 per ton at the point where shipment begins.

The Susquehanna and Schuylkill as well as the Lehigh are surrendering the buried coal. With closer and more scientific working up of the coal as it comes from the mines, the ugly, disfiguring culm dumps spread over a naturally picturesque landscape will be a thing of the past, and perhaps the small river industry too, but hardly for a generation or more.

NOTES FROM NELA RESEARCH LABORATORY.*

THE QUALITY OF LIGHT FROM AN ILLUMINANT AS INDICATED BY ITS COLOR TEMPERATURE.

By E. P. Hyde and W. E. Forsythe.

The importance of quality in the light from various illuminants has been recognized for some time, and various methods have been worked out to designate this important characteristic. The spectrophotometer may be used to determine the relative distribution of intensity in the various wave-lengths of the visible spectrum, and the colorimeters of Ives and of Nutting indicate component elements which may be used to specify the color of a light-source. But it is difficult, from such data, to visualize the resultant color.

It has been found by experiment that the light from most, but not all, ordinary illuminants can be matched in color by the light from a black body operating at some particular temperature, which is called the " color " temperature of the source in question. In the case of candles, oil lamps, ordinary gas flames, and incandescent electric lamps, it is found that, when operating at a color match, the distribution of energy in the visible spectrum of the black body and the source is quite closely the same, although this would not necessarily follow.

Data have been obtained on the color temperatures of various illuminants, and it is suggested that these be made the basis of a color scale for sources whose light is sufficiently near that of a black body in color to permit of comparison.

For sources, such for example as the Welsbach mantle, whose light cannot be matched in color with that from a black body at any temperature, the method outlined above is not entirely satisfactory, but the authors have in mind a possible modification of this method which may extend its applicability to almost all practical sources. Experiment has shown that it is possible to specify the quality of light from the Welsbach mantle, whose color in somewhat greenish, by stating the temperature of a black body whose light when mixed with that transmitted by a blue-green filter and coming from a black body at a definite temperature matches that from the mantle. Further investigation is planned to determine the feasibility of some such method for those sources whose colors do not lie on the scale of color of a black body at various temperatures.

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* Communicated by the Director.

Data for some of the most common illuminants are given in the table.

COLOR TEMPERATURE OF VARIOUS ILLUMINANTS.

Source	Color temperature ° K.
Gas flame, fish tail burner*	1870
Hefner	1875
Pentane (10 candle-power standard)	1914
Candle:	
Paraffin	1920
Sperm	1925
Kerosene lamp:	
Round wick	1915
Flat wick	2045
Acetylene (as a whole)	2368
One spot	2448
2.3 w.p.h.c. Nernst glower	2388
4 0 w.p.h.c. carbon	2070
3.1 w.p.h.c. treated carbon	2153
2.5 w.p.h.c. Gem	2183
2.0 w.p.h.c. Osmium	2176
2.0 w.p h.c. Tantalum	2249
1.25 w.p.h.c. tungsten	2385
0.9 w.p.h c. tungsten	2543
0.5 w.p.h.c. gas-filled tungsten	2900 †

* Coal and water gas mixture. Approximately 600 B. T. U.

† Approximate. Differs with different lamps.

From these data and those on the black-body brightness temperatures, the brightnesses of the various illuminants may be computed.

THE REFLECTIVITY OF TUNGSTEN IN THE INFRA-RED.

By W. Weniger and A. H. Pfund.

IN this investigation on the reflectivity of tungsten, there were measured for the wave-length interval 0.59μ to 4.0μ

(1) The absolute reflectivity at room temperature, and

(2) The change in reflectivity from that at room temperature for several temperatures up to 2056° K.

Three tungsten mirrors were used, one polished Coolidge X-ray target, and two polished flattened wires mounted in evacuated soft glass bulbs, with terminals for heating electrically. All mirrors gave concordant values at the points at which they were compared. The spectrometer was provided with a fluorite prism and a bolometer. The length of air-path, the number of silvered reflecting surfaces, and the angles of reflection from these surfaces were kept constant in all measurements. Slit-width corrections were applied. The temperatures were measured by Worthing and Forsythe on an optical pyrometer.

The results obtained are summarized in the following table:

Wave-length in μ	Absolute reflectivity at room temperature in per cent.	Per cent. increase in reflectivity in going from room temperature to			
		1377° K.	1628° K.	1853° K.	2056° K.
0.67	51	+6.0	+7.4	+8.7	+9.8
0.80	55				+8.2
1.27	70	0.0	0.0	0.0	0.0
1.90	83	−6.6	−8.2	−9.6	−11.0
2.00	85	−7.5	−9.3	−10.9	−12.3
2.90	92	−7.7	−9.4	−11.1	−12.5
4.00	93				−12.5

THE ROTATION OF CONSTANT DEVIATION PRISMS.

By W. E. Forsythe.

THE constant deviation prism, as used in the well-known Hilger spectroscope, is so mounted and so rotated that the incident beam passes through the prism in such a manner that its axis coincides very closely with the axis of the prism. As a result of this arrangement light of only two wave-lengths can pass through the prism at exactly minimum deviation. For all other wave-lengths there is a lateral shift of the beam.

If the spectroscope is to be used to measure radiation rather than to locate spectral lines, a fixed diaphragm is necessary. In this case, at least, it would be well to have the prism so mounted and so rotated that it will remain in the position of minimum deviation.

It can be shown mathematically and has been found experimentally that if the prism be rotated about the line of intersection of the bisector of the ninety-degree angle of the prism and the reflecting face, the prism will remain in the position of minimum deviation for all wave-lengths.

A method has been worked out of locating the prism on the prism table very close to the correct position. It has been found convenient to have the prism table equipped with stops so that the prism can be removed and replaced on the prism table in the proper position without as much trouble as is ordinarily encountered.

NELA PARK, CLEVELAND, OHIO,
February 20, 1917

The Chemical Industry of Switzerland. ANON. (*Metallurgical and Chemical Engineering,* vol. xvi, No. 2, p. 78, January 15, 1917.)—Switzerland is one of those countries which, although covered by a vast area of mountainous terrain, is exceptionally poor in all kinds of mineral resources. The main raw materials, coal and iron, are practically lacking and necessitate their importation from the surrounding nations. Water power is, however, available and is being developed to its full capacity. The war has to a great extent thrown this small country on its own resources as far as power for industrial purposes is concerned, but at the best this power source is insufficient to supply the 107 chemical plants at present in operation. The bulk of the coal, therefore, is at present obtained from Germany. Previous to the war coal was also imported from France.

Practically all the chemical engineers of the country are trained at the polytechnicum of Zurich and the University of Zurich, both being independent of one another and financed by the government. The most important chemical industry is undoubtedly the manufacture of synthetic dyes. Besides this branch, Switzerland manufactures pharmaceutical products and chemicals for industrial purposes. These are two types of colors produced, namely, vegetable dyes, chiefly from logwood, and coal tar colors. At least 106 synthetic dyes are at present produced by the various dye factories of the country. These dyes at present are mainly shipped to England and France, but would under normal conditions be available for the American market. Among the pharmaceutical preparations manufactured are protargol, collargol, and itral, a new preparation of a silver protein compound carrying 30 per cent. silver and sold under various trade names. There are also produced, alkaloids, perfumes, cosmetics, and, for industrial purposes, acid potassium tartrate, boric acid, phosphoric acid, sodium, tanning extracts, glycerin, methyl alcohol, coal-tar derivatives, benzychloride, glue and gelatin. The first chemical factory was built in the year 1764. From that time up to date the number has increased to 107.

THE FRANKLIN INSTITUTE

(Proceedings of the Stated Meeting held Wednesday, February 21, 1917.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 21, 1917.

PRESIDENT DR. WALTON CLARK *in the Chair.*

Additions to membership since last report, 11.

Mr. William C. Wetherill, chairman of the Committee on Science and the Arts, reported the condition of the work of the committee.

The standing committees for the year 1917–1918 were announced.

Mr. Alfred W. Gibbs made the following statement:

"In order to meet the formalities necessary in the sale, by the Trustees of the Institute, of the Doylestown Farm, which came to the Institute under the will of the late William H. Wahl, it is necessary that the following resolution be passed:

"'*Resolved,* That the title to the tract of land situated in the Township of Doylestown, County of Bucks and State of Pennsylvania, containing twenty-four acres of land more or less, recently devised to The Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts, under the will of William H. Wahl, deceased, be transferred to the Board of Trustees, in accordance with Section I, Article I, of the By-Laws of the Institute. And the President and Secretary of the Institute are hereby authorized and directed to execute the necessary deed for the purpose.'"

The resolution was duly seconded and passed unanimously.

The paper of the evening, entitled "Reclaiming the Everglades of Florida," was presented by Dr. Isham Randolph, Consulting Engineer, Chicago, Ill. The speaker described his experience in Florida during the past four years, and the work which has been done in the Everglades, along the Kissimmee River, on Lake Okeechobee, on the headwaters of the St. John's River, and on Biscayne Bay. He referred to the beauties of Florida, the productiveness of its swamp and other lands, and outlined the engineering difficulties being overcome in its development. The subject was illustrated by lantern slides.

At the close of the paper a vote of thanks was extended to the speaker and the meeting adjourned.

R. B. OWENS,
Secretary.

STANDING COMMITTEES, 1917.

OF THE BOARD.

ELECTIONS AND RESIGNATIONS.

Alfred W. Gibbs, Chairman,
Kern Dodge,
W. C. L. Eglin,
George R. Henderson,
George D. Rosengarten.

ENDOWMENT.

Coleman Sellers, Jr., Chairman,
Alfred C. Harrison,
G. H. Clamer,
Richard Waln Meirs,
Wm. Chattin Wetherill.

EXECUTIVE.

E. H. Sanborn, Chairman,
Charles Day,
Walton Forstall,
Alfred C. Harrison,
Richard Waln Meirs.

EXHIBITIONS.

Francis T. Chambers, Chairman,
Nathan Hayward,
C. A. Hexamer,
Marshall S. Morgan,
Benjamin Franklin,

INSTRUCTION.

Lawrence T. Paul, Chairman,
George A. Hoadley,
Harry F. Keller,
Edw. V. McCaffrey,
James S. Rogers.

PUBLICATIONS.

Louis E. Levy, Chairman,
W. C. L. Eglin,
George A. Hoadley,
E. H. Sanborn,
George D. Rosengarten.

SECTIONAL ARRANGEMENTS.

Charles Day, Chairman,
Theobald F. Clark,
Harry F. Keller,
Robert W. Lesley,
Louis E. Levy.

STOCKS AND FINANCE.

Walton Forstall, Chairman,
Cyrus Borgner,
Alfred C. Harrison,
Richard Waln Meirs,
E. H. Sanborn.

OF THE INSTITUTE.

LIBRARY.

H. J. M. Creighton,
George A. Hoadley,
Harry F. Keller,
Gaetano Lanza,
Henry Leffmann,
Louis E. Levy,
Marshall S. Morgan,
Paul Spencer,
George F. Stradling,
William Chattin Wetherill.

MEETINGS.

Gellert Alleman,
Charles Baskerville,
G. H. Clamer,
Allerton S. Cushman,
George R. Henderson,
Herbert E. Ives,
A. E. Kennelly,
M. M. Price,
James S. Rogers,
George D. Rosengarten.

MUSEUM.

J. Snowden Bell,
Hugo Bilgram,
Arthur L. Church,
Fred. H. Colvin,
Henry F. Colvin,
Charles Day,
George A. Hoadley,
Henry Howson,
A. E. Outerbridge, Jr.,
Coleman Sellers, Jr.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, February 7, 1917.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 7, 1917.

MR. W. C. WETHERILL *in the Chair.*

The following report was presented for first reading:

No 2681.—International Money Machine.

Representatives of the International Money Machine Company appeared before the Committee and explained the operation and construction of the Money Machine.

The following report was presented for final action:

No. 2668.—Linear Hot-Wire Anemometer.

Howard N. Potts Medal to Prof. Louis Vessot King, of McGill University, Montreal, Canada, adopted.

R. B. OWENS,
Secretary.

SECTIONS.

Mechanical and Engineering Section.—A joint meeting of the Section and the American Society of Mechanical Engineers was held in the Hall of the Institute on Thursday, February 1, 1917, at 8 P.M.

Mr. Emmett B. Carter, Chairman of the local Section of the American Society of Mechanical Engineers, occupied the chair.

Mr. Carter introduced Mr. C. J. Ramsburg, Vice-president, H. Koppers Company and Pittsburgh By-Product Coking Company, Pittsburgh, Pa., who delivered a lecture entitled "The By-Product Coking Industry."

This lecture, which was fully illustrated by the use of lantern slides and moving pictures, treated of the design, construction and operation of the modern by-product plant; coal used in by-product coking; coke structures as affected by coals; conditions affecting the efficiency of operation and recovery; future of the industry. Special attention was given to benzol and benzol recovery.

After an interesting discussion, a vote of thanks was extended to the speaker.

Adjourned,

T. R. PARRRISH,
Acting Secretary.

Electrical Section.—A joint meeting of the Section and the Philadelphia Section of the American Institute of Electrical Engineers was held in the Hall of the Institute on Thursday, February 8, 1917, at 8 P.M.

Mr. Charles E. Bonine and Mr. H. P. Liversidge presided jointly.

Alexander Gray, M. Sc., Professor of Electrical Engineering, Cornell University, Ithaca, N. Y., delivered a lecture entitled "Modern Dynamo Electrical Machinery, With Special Reference to Power and Traction Uses." The recent developments in electrical machinery were discussed under the following heads:

Discussion of the limits of direct-current machines.

Development of direct-current machines in the last ten years, showing the effect of interpoles and compensating windings on the speed and output.

Development of turbo and of water-wheel driven alternators, with a discussion of the problems of mechanical design and ventilation; also the effect of the automatic regulator on the design and on the output.

Development of the Rotary Converter, giving the reasons for the success of the sixty-cycle rotary in large sizes and for the high speeds now in use.

After an interesting discussion, a rising vote of thanks was extended to the speaker, and the meeting adjourned.

T. R. PARRISH,
Acting Secretary.

Mining and Metallurgical Section.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, February 15, 1917, at 8 P.M.

Prof. A. E. Outerbridge, Jr., occupied the chair.

Prof. Outerbridge introduced Mr. Howard W. DuBois, Consulting Mining Engineer, of Philadelphia, Pa., who delivered a lecture entitled "Oil Concentration of Ores."

The radical change in established methods of ore concentration in a comparatively short period of time by the introduction of the oil flotation process, with its resulting extraordinary economies, constitutes one of the most striking chapters in the history of ore milling operations. The oil process is chiefly characterized by the use of extremely small quantities of oil. The action of the oil appears to be restricted to coating the surface of the metallic sulphide particles with a thin film, making them attractive to air particles in the water and thus causing them to float, while the gangue, which is non-metallic, is wetted and sinks. The origin of this already widely applicable process, the principles of its operation, and its most recent developments were discussed.

After an interesting discussion, the thanks of the meeting were extended to the speaker.

Adjourned,

T. R. PARRISH,
Acting Secretary.

MEMBERSHIP NOTES.

Stated Meeting, Board of Managers, February 14, 1917.

ELECTIONS TO MEMBERSHIP.

RESIDENT.

MR. ARTHUR N. BLUM, chief engineer, Henry Disston & Sons, Inc., Tacony, Philadelphia, Pa.

MR. JOHN GAREY, chemist, American Dyewood Company, and for mail, in care of Y. M. C. A., Chester, Pa.

MR. ANTHONY M. HANCE, manufacturing chemist, 201 Walnut Place, Philadelphia, Pa.

MR. HENRY J. STEUBER, chemist, 509 South Tenth Street, Philadelphia, Pa.

NON-RESIDENT.

Dr. A. D. Chambers, chemical engineer, E. I. du Pont de Nemours and Company, and for mail, 1519 Franklin Street, Wilmington, Del.

Mr. J. King McLanahan, president, McLanahan & Stone Machine Company, Hollidaysburg, Pa.

Mr. Frank S. MacGregor, Development Department, E. I. du Pont de Nemours and Company, 452 du Pont Building, Wilmington, Del.

Mr. Alexander Ernest Reoch, chief engineer, Marconi Wireless Telegraph Company of Canada, Ltd., Montreal, P. Q., Canada.

Mr. Charles E. Richardson, secretary, The Surface Combustion Company, and for mail, 63 East Fifty-ninth Street, New York, N. Y.

Mr. F. W. Sperr, Jr., chief chemist, H. Koppers Company Laboratory, Mellon Institute, Pittsburgh, Pa.

Mr. Hugh P. Tiemann, assistant metallurgical engineer, Carnegie Steel Company, Pittsburgh, Pa.

CHANGES OF ADDRESS.

Mr. Harold V. Coes, care of Gunn, Richards & Co., 43 Exchange Place, New York, N. Y.

Prof. W. S. Franklin, Orange City, Florida.

Dr. Jacob S. Goldbaum, 4636 Walnut Street, Philadelphia, Pa.

Mr. William J. Hammer, 55 Liberty Street, New York, N. Y.

Mr. Elmer K. Hiles, 5712 Hampton Street, Pittsburgh, Pa.

Mr. Edwin W. Kelly, 737 West Van Buren Street, Chicago, Ill.

Mr. Henry M. Kolb, 1400 Widener Building, Philadelphia, Pa.

Mr. Morton G. Lloyd, Bureau of Standards, Washington, D. C.

Mr. Frank M. Masters, 204 Locust Street, Harrisburg, Pa.

Mr. Fred. J. Miller, 374 Broadway, New York, N. Y.

Dr. R. W. Ruprecht, care of F. W. Tunnell & Co., Wheatsheaf Lane and Gaul Street, Philadelphia, Pa.

Mr. Oscar L. Schehl, care of American Machine and Foundry Co., Brooklyn, N. Y.

Mr. A. F. Shattuck, Angelus Hotel, Los Angeles, Cal.

NECROLOGY.

Mr. Robert D. Jenks, Esq., was born at Enterprise, Florida, in 1875 and died in Philadelphia, on January 22, 1917.

He was educated at the Penn Charter School in Philadelphia and Harvard University. Later he entered the University of Pennsylvania and was graduated from its law department in 1901. In the practice of law he devoted special attention to railroad rate cases and questions relating to interstate commerce.

Mr. Jenks was the author of " A Handbook of Commercial Law for Business Men " and made frequent contributions on interestate commerce law to the legal magazines.

He was greatly interested in civil service reform and was a member of the national and local organizations devoted to the furtherance of the matters.

Mr. Jenks became a member of The Franklin Institute in 1898.

Prof. Arthur Beardsley, Swarthmore, Pa.

Mr. Thomas C. McCollom, U.S.N., retired, 4606 Springfield Avenue, Philadelphia, Pa.

Mr. Alex. P. Robinson, 4603 Woolworth Building, New York City, N. Y.

LIBRARY NOTES.

PURCHASES.

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American Concrete Institute.—Proceedings. Vol. 12. 1916.
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Harding, L. A., and Willard, A. C.—Mechanical Equipment of Buildings. 1916.
Harger, W. G., and Bonney, E. A.—Handbook for Highway Engineers. 1916.
Luckiesh, M.—Light and Shade and Their Applications. 1916.
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GIFTS.

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Doehler Die-Casting Company, Creating an Industry. Brooklyn, 1916. (From the Company.)

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Harrison Safety Boiler Works, Catalogue No. 710, Cochrane Heaters. Philadelphia, 1916. (From the Works.)

Hudson and Thurber Company, Catalog D. Minneapolis, Minn., 1914. (From the Company.)

Hunt, Rodney, Machine Company, Catalogue No. 30, Water Controlling Apparatus. Orange, Mass., 1916. (From the Company.)

Iddings, Joseph P., The Problem of Volcanism. New Haven, Conn., 1914. (From Yale University.)

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New Method for Charging Storage Batteries. ANON. (*Electrical World,* vol. 68, No. 26, December 23, 1916.)—In a recent patent (No. 1,205,620) Varian M. Harris, Chicago, Ill., the inventor, gives an interesting theory of the apparent inefficiency observed when charging storage batteries from rectified or pulsating circuits. In the charging of a storage battery an appreciable time element is necessary for the chemical reactions to take place within the battery, and for that reason if a phase wave is cut at the points which correspond in voltage to the voltage of the battery, the latter will not be charged. since it does not respond instantaneously to the current which passes into it, and sparking will result.

In order to overcome this difficulty the phase waves should be cut at appropriate points so that the rectified current passes to the battery at a voltage considerably below the normal voltage of the battery. The chemical changes immediately begin to take place in the battery, and by thus allowing the current to flow to the battery at a decreased voltage the chemical changes have become sufficiently started so that when the voltage of rectified current reaches the normal voltage of the battery, the rectified current is allowed to flow to the battery. This result is accomplished by constructing the segments of the mechanical rectifier of such a width that the phase waves of the rectified current are cut at a voltage sufficiently below the normal voltage of the battery that the time during which the rectified current is increasing up to the voltage of the battery is sufficient to overcome the electrolytic lag of the latter.

CURRENT TOPICS.

The Root Mean Square Current Meter. D. C. Hershberger. (*The Electric Journal,* vol. xiv, No. 2, p. 59, February, 1917.)—The heating effect of a variable electric current is proportional to the square root of the mean square current, which obviously is the square root of the average of the squares of the instantaneous current values for a given period of time, taken at infinitely short intervals. The longer these intervals, the more inaccurate will the results be, especially under rapidly changing current conditions. Hence, in determining the value of actual test, it is necessary to take current readings as frequently as possible, equal time intervals usually being most convenient. The determination of the root mean square current by ammeter method, where the current values are changing rapidly, is not only difficult, but tiresome and expensive work, especially when readings must be taken over a considerable period of time on a moving car or locomotive.

It is well known that the continuous capacity of any piece of electrical apparatus is limited by the amount of heat it can dissipate. In most electrical apparatus, the principal sources of internal heat are the copper and iron losses. In some apparatus these losses are entirely independent. In a series machine, the iron loss at a given voltage depends upon the current. In a railway motor, for instance, the generation of heat is due to both copper and iron loss, but its capacity is determined by the r.m.s. current (sometimes called the equivalent heating current), at which it can operate without exceeding a safe rise in temperature. Many other types of machines designed for intermittent service are given r.m.s. current ratings.

In order to measure this equivalent heating current expeditiously and economically, Mr. J. L. Davis in 1910 invented the original root mean square current meter. The measurement of current with this meter depends upon the generation of heat by passing all or part of the current through a resistance immersed in a given quantity of water. Since the heat generated is proportional to the square of the current, the temperature of the water will (except for heat losses) be raised in the same proportion. Every change of current will be virtually integrated, on the basis of the square of the current and elapsed time, by the rise in temperature of the water. Rapid radiation of heat is prevented by the use of a vacuum jar. The original meter consists of a "Thermos" bottle or similar vacuum jar containing water into which are immersed a resistance coil and a thermometer. The supporting terminals of the coil and thermometer pass through the cork. In operation, the temperature of the water tends to be slightly higher at the top and stirring vanes attached to a rod are provided for mixing the water prior to reading the temperature. Starting with a definite quantity of distilled water at 20 degrees C., the instrument is kept in the circuit for a period of approximately two hours, provided the r.m.s. current does not exceed the rating of the resistance element or shunt. The test can, in fact, be started at any temperature which will permit it to be finished without bringing the water too near the boiling point. A correction factor is applied for initial temperatures which are more than 5 degrees above or below 20 degrees C. Equivalent current is read from temperature-time curves for different currents, determined from constant current readings. Results of careful laboratory tests show the error of the instrument is less than two per cent.

Some Special Applications of Pinhole Photography. ANON. (*British Journal of Photography*, vol. lxiv, No. 2959, p. 27, January 19, 1917.)—Very few photographers seem to appreciate what can be done with a pinhole when a lens suitable for a given purpose is not at hand. It happens sometimes that no lens of sufficiently great or perhaps short enough focal length is available, or possibly one that will cover a sufficiently wide angle. If, however, we can put up with less perfect definition and also long exposure, a great many things can be done with a simple pinhole, for focal length is a property that is practically infinitely elastic with a pinhole, while the angle of view can be any size up to very wide limits with a good hole. Also, depth is unlimited. As regards definition, the lack of sharpness is not nearly so great as is likely to be imagined by those unacquainted with what can be done. A good pinhole negative will give a lantern slide that will bear a considerable degree of enlargement on the lantern screen without any undue fuzziness. There is usually a certain amount of grain apparent, owing probably to the peculiar diffraction effects which go to form the image, but this need not be seriously objectionable. As regards focal length, we may consider anything feasible from about 40 inches down to an inch or less, consequently at small expense it is possible to secure effects that otherwise would be out of the question, neither 40-inch nor 1-inch lenses being available, as a rule.

Some of the most interesting results obtainable with the pinhole are those produced with exceedingly short extension, say an inch or so, for then we can get some idea of what the world looks like to some of the small creatures that inhabit it. Depth problems are immaterial to the pinhole, as all distances are alike to it. Using a camera consisting merely of a metal lantern slide box with a pinhole fitted with a small shutter, most interesting results in under-water photography have been obtained. For more ordinary purposes, it is often desirable to see beforehand on the focussing screen what amount of the subject is to be included on the plate. It is not possible to see the pinhole image on the screen, but if we substitute for the pinhole a hole about a quarter of an inch in diameter, we can see the subject through it from any part of the plate area. In this way we practically turn the camera into a finder of the frame type, and this is all that is necessary, actual focussing being neither required nor possible.

Ferro-cerium and Other Pyrophoric Alloys. C. R. BOHM. (*Metal Record and Electroplater,* vol. iii, No. 1, p. 8, January, 1917.)—About the year 1903, Welsbach discovered that certain alloys of the rare earths, when filed, gave off showers of bright sparks which would readily ignite inflammable gases. It was subsequently found that the best results were secured when employing an alloy carrying about 65 per cent. cerium earth metals and about 35 per cent. iron. The same action takes place with these alloys as with the flint and steel, except that a spark is more easily produced than with the primitive tinder-box. The mixture of cerium earth metals, often called misch metal, consists mainly of the elements cerium, lanthanum, didymium, neodymium, praseodymium and samarium. All of these metals are white or light yellow in color and are not readily oxidized in air. When first produced, the price of ferro-cerium alloys was $60 per kilogram. Later, this was reduced to $12 per kilogram, and in 1913 to about $4.60 per kilogram. The present return to the old price is, of course, due to the abnormal conditions which have affected nearly all products.

While the original pyrophoric alloy or ferro-cerium manufactured by Welsbach contains nearly 40 per cent. of iron, the competing products possess only about 15 per cent. of iron, and for the purpose of hardening, about 2 per cent. of antimony or bismuth is added. Silicon is, of course, found in nearly all ferro-cerium alloys because it is either contained in the raw misch metal as an impurity, or has been absorbed from the clay crucibles in which the alloy is often produced. To insure a low-melting and smooth-casting pyrophoric alloy, certain manufacturers add about 5 per cent of copper. Most manufacturers produce ferro-cerium by the electrolysis of the anhydrous chlorides of cerium, lanthanum, didymium, etc., and it is necessary that cheap current be available. Many manufacturers use ordinary graphite or clay crucibles with large iron cathodes; others use water-jacketed iron crucibles.

Welding Glass in Optical Contact. G. R. PARKER AND A. J. DALLADAY. (*Engineering,* vol. ciii, No. 2663, p. 23, January 12, 1917.)—For many optical researches glass cells are wanted, formed by two strictly parallel walls or windows, and different pieces of glass, lenses and prisms, etc., have frequently to be united in such a way as to keep the surfaces optically true. Glass surfaces can be polished without difficulty to be so nearly plane or so nearly of the same curvature that they show less than one interference fringe per inch when placed together and examined by light reflected from the interfaces. These surfaces may be brought into optical contact so that the two pieces of glass act optically as if they were one block by applying a pressure of several pounds per square inch. Unions so made may be easily separated by sudden heating or cooling by a shearing force, or by the application of liquids which gradually creep in between the surfaces.

A cell constructed of plates of glass in optical contact with a separating piece of U-shape could be made very accurately parallel; but the surfaces could be too easily separated again. Various cements like Canada balsam are, of course, largely used in optical combinations. But it is difficult by their aid to insure parallelism within one minute of the arc, and if the walls of the cell form a wedge of an angle of only a few seconds, instead of a cavity with plane-parallel walls, interference work may be seriously impaired. If pieces of glass could be welded without affecting the optical truth of their surfaces, considerable advantages would be gained. Attempts to effect such optical junctions by heating have been unsuccessful so far, though bifocal lenses are made by uniting two lenses either by cementing or by fusing; in the latter case, however, the flint is readily fused, and optically true contact is not aimed at.

The authors have succeeded by experiments in the research laboratories of Messrs. Adam Hilger, Limited, in producing some excellent specimens of optical welding. The secret of success lies, as might be expected, in the selection of the proper temperatures and pressures. It was found essential that the temperature at which union took place should not only be far below the melting point of the glasses to be joined, but also below the annealing temperature, for even at that latter temperature very slight strain would cause deformation of worked glass surfaces. At 60 degrees C., below the annealing temperature, it was found that two pieces of glass in optical contact would unite within an hour, and any slight deformation produced by the compression could be remedied by a few strokes of the polishing tool.

Lithographic Stone in the United States. ANON. (*U. S. Geological Survey Press Bulletin,* No. 308, February, 1917.)—In 1916 for the first time there was a considerable production of lithographic stone in this country. This production, according to information received by G. F. Loughlin, of the United States Geological Survey, Department of the Interior, was made by the Kentucky Lithograph Stone Company, which has quarries at Brandenburg, Ky., and an office in Louisville. In 1916 the company sold 40,000 pounds of finished stone at prices ranging from 2½ to 27 cents a pound. For some years previous small quantities had been sold occasionally in Louisville, but in 1916 the stone was shipped to buyers as far away as Cleveland, Washington, New York and Boston.

The quarry at Brandenburg contains three distinct beds from which lithographic stone may be obtained. Two of these beds are about 3 feet thick and one 9 to 10 feet thick. They are separated by beds of limestone of other varieties and make up only about 20 per cent. of the stone that must be removed. The remaining 80 per cent., however, is available for crushed and pulverized limestone, chicken grit, and other uses, and considerable quantities were marketed for these purposes in 1916.

The greatest difficulty in the development of lithographic-stone quarries in the United States has been the high cost of quarrying and preparing the stone in competition with the well-known Bavarian stone. Much of this stone is reported to occur in thin layers that require only planing and polishing before use, whereas all known deposits in the United States that are at all suitable for lithographic work occur in more massive beds that must first be sawed into slabs of proper thickness. High cost of labor in the United States and of railroad as compared with ocean transportation have also stood in the way of the domestic industry.

Quarrying of the Bavarian stone, however, involves the handling of large quantities of waste, and the waste piles around the quarries to-day form hills of considerable size. The marketing of crushed stone and similar products from the Brandenburg quarry should go far toward eliminating the cost of quarrying from the expense of preparing lithographic stone. With this advantage it may be possible, even after the European war is over, to market the Kentucky stone in competition with the Bavarian stone, the better grades of which under normal conditions bring 5 to 6 cents a pound for 10 by 12 inch slabs, and the poorer grades 1½ cents a pound for slabs of the same size.

Uses of Colored Glass. H. P. GAGE. (*Transactions of the Illuminating Engineering Society,* vol. xi, No. 9, p. 1059, December 30, 1916.)—The uses of color in illuminating engineering may be divided into direct decorative effects, colored illumination for æsthetic effects, and illumination for specific visual effects. The direct decorative uses are seen in the stained glass windows of churches and in the coloring of illuminating reflectors and shades. Such decoration borders on the colored enamel such as is used in china and porcelain. Colored illumination is used in stage lighting and to produce the much desired warm tones in interior illumination. In these cases the light from the original source is filtered through either a colored lamp bulb or through a colored enclosing globe or even reflected from a colored reflector. The illumination for specific visual effects includes protection either of the eye or the work from harmful radiations. An example of the latter is the use of a red light for photographic purposes where the plate is not sensitive to red and the eye is.

Protection of the eye from harmful radiation may consist in the removal of the ultra-violet such as is met with in experimenting with the arc lamp or in arc welding. It is, moreover, possible, although the eye was developed for use in natural daylight, that in such daylight the radiation in the ultra-violet is harmful and that under favorable conditions it will cause cataract in the course of several years. Excess of visible or luminous radiation produces discomfort to the eye, and if the eye is continuously exposed to too great illumination, injury results. Intra-red radiation when not accompanied by excess of ultra-violet or luminous radiation is not generally regarded as harmful. It must, however, be recognized that such radiation is uncomfortable to the workers in low temperature light sources such as glass and steel furnaces. Anything that causes continued discomfort to the eye in the course of years must result in permanent damage. In this connection, it is interesting to note that the use of ordinary clear spectacles reduces the discomfort from such light sources.

As aids to vision, monochromatic light sources have been found to give the greatest possible visual actuity. Such monochromatic light may be the mercury arc and a suitable glass; or the spectrum of white light shortened by filtering through colored glass. The use of " noglare " and orange glass reduces the length of the spectrum to about one-half and one-fourth respectively. It appears, however, that the increase in visual acuity is accompanied by a corresponding increase in eye fatigue and, for visual comfort, the complete spectrum is most desirable. This seems reasonable because the eyes of the human race were developed in an illumination of natural daylight.

For correct color rendering, that is, the same as obtained by natural daylight, the light must have been the same distribution of energy as natural daylight and must appear the same color. Such artificial lights are the Moore-light, the arc light, filtered through a checker board made of colored glasses, or the light from a tungsten lamp filtered through suitable dyed gelatines or colored glasses. Practical glass filters have been made which transmit approximately 15 per cent of the light from the gas-filled tungsten lamp operating at 2850° absolute. This low transmission is an objection from the standpoint of the user, but is not prohibitive considering the high original efficiency of gas-filled lamps.

The Thermo-Electric Properties of Fused Metals. C. R. DARLING and A. W. GRACE. (*Proceedings of the Physical Society of London, vol.* xxix, Part I, p. 82, December 15, 1916.)—In measuring high temperatures by the thermo-electric method, it has hitherto been customary to regard the melting point of either member of the couple of the extreme temperature capable of being measured. As pyrometers of this type are now constructed, the fusion of either metal causes a break in the circuit, and hence for temperatures exceeding 1000° C., it has been found necessary to use junctions of platinum and an alloy of platinum and rhodium. If, however, a pyrometer could be arranged so that the fusion of either member of the junction would not destroy the circuit, it might be possible to use cheap metals over very high ranges of temperatures, provided that the boiling points were not too nearly approached. The boiling points of metals have been investigated by Greenwood, who has shown that the values for common metals frequently exceed 2000° C.; tin, for example, boiling at 2270°, copper at 2310°, and iron at 2450°. It would, therefore, appear feasible, in a specially designed pyrometer, to measure temperature as high as 1500°, and probably higher, by using common metals in the molten condition, provided their thermo-electric properties were suitable. Further, in the case of bismuth, which boils at 1420°, the high E.M.F. developed when this metal is joined to iron, copper, etc., suggests that possibility of delicate measurements over a range from 0° to 800° or 1000°, again assuming that the thermo-electric properties after fusion are satisfactory.

With these objects in view, an investigation was commenced by the first named author about three years ago, but owing to the abnormal conditions prevailing, progress has been very slow. As a preliminary, it was necessary to determine whether any notable change in thermo-electric properties was caused by fusion, and the results arrived at in this connection were given at the meeting of the Society held on June 30, 1916. It was then shown that in the cases of lead, tin, zinc and cadmium, using a variety of metals as second members of the junctions, that no perceptible break occurred in the continuity of curves obtained by plotting E.M.F. against temperature, either at fusion or at any subsequent stage up to 700° C. With bismuth, however, several cases were noted in which the E.M.F. remained nearly constant after fusion over a wide range of temperature, reproducing the phenomenon of thermo-electric "halt" observed by Barrett with a junction of iron and an alloy of iron, nickel and manganese containing 1.2 per cent. of carbon This property of molten bismuth has since been more carefully examined, and also the behavior of molten bismuth in cases where this halt is not obtained. It is evident from the results that molten bismuth cannot be utilized for the measurement of temperatures. Its thermo-electric properties after fusion are different from those of tin, lead, zinc and cadmium, all of which show no marked discontinuity as the result of fusion. Preliminary experiments with antimony suggest a similarity to bismuth in this respect.

Mistakes Regarding Focal Lengths and Lens Stops. F. C. LAMBERT. (*The Photographic Journal of America*, vol. liv, No. 1, p. 22, January, 1917.)—Two questions which constantly arise among users of photographic apparatus are how to measure the focal length of a lens and how to measure the f/–values of the stops. For very rough-and-ready purposes it suffices to focus the lens on any distant object, measure the distance from the ground glass, on image plane, to the stop, and call this the focal length. Also if this value of the focal length be divided by the diameter of the stop, we get the f/–value of the stop. This is only correct when, as happens somewhat rarely, the posterior nodal point, or Ganss plane, happens to coincide with the stop. The nodal point may be found by trial. The method employed is to support the lens in a horizontal position upon a vertical axis. A sharp wire nail driven into a cork will answer for the vertical axis and the lens may be held against it in place by hand. Having brought a screen opposite the lens in such a position that a distant object is accurately focused upon it, the pivot is adjusted normally to the screen until any slight twist of the lens in the horizontal plane about the pivot point will produce no motion of the image on the screen. When this condition is secured, the distance of the pivot point from the screen is the true back focal point. By repeating the process with the lens in reversed position, the front focal point may be found. These points may be marked upon the tube for future reference.

The true f/–value of a stop is found by dividing the focal length by the diameter of the cylinder or pencil of light *entering the lens.* In the case of a single lens with a stop in *front* of the lens, the diameter of the stop measures the entrant pencil. But where the stop is behind the lens, the diameter of the stop is smaller than the entrant cylinder. Hence in this case, if we divide the diameter of the stop into the focal length, we should get the stop number too large. The true lens-face value of the stop may be measured by standing the lens vertically and placing across the diameter a card held on edge so that a series of long graduations drawn upon it will be substantially parallel to the axis of the lens. On looking down along the lines, one of which is arranged to agree precisely with one end of the apparent diameter of the stop, the distance to the opposite diameter can be read from the scale.

French and German Light Field Artillery. A. DUMAS. (*Le Genie Civil,* vol. lxv, No. 21, September 19, 1914.)—(Descriptions of later date of this equipment have appeared, but none available appears more complete or authoritative than the one from which this abstract is made.—ED.) The French 75 millimeter rapid fire field gun, so frequently mentioned in war despatches, is not in its essential features a very recent production. It dates from 1897 when it was adopted to replace a slow firing arm of 90 millimeters calibre of a well-known type. It is better adapted to modern requirements and has a maximum rate of fire of 20 shots per minute. This rate of fire is attained, not by any one revolutionary feature of design but by the refinement of methods of operation now common in various forms to all light artillery. Prominent among these are the use of fixed (cartridge) ammunition, a long-recoil mount, and a quick-acting breech mechanism.

The calibre of 75 millimeters was adopted with the object of reducing the weight as far as practicable. Its 33-calibre length of barrel is somewhat greater than is generally employed in a field gun. The barrel is, as usual, a steel forging of suitable quality reinforced with a jacket. Departing from the common practice of hot shrinking, the jacket is forced in place cold, a method of assembling which avoids the molecular changes consequent upon hot shrinkage. The breech block, although screwed in place, is not of the interrupted screw system now extensively employed in guns of all calibres. In its elemental features the breech is closed by a threaded cylinder, whose axis is parallel to the axis of the bore somewhat greater in diameter than twice the bore. The breech housing into which this is fitted is eccentric with the bore so that an orifice in the block at the same eccentricity with the axis of the block is diametrically opposite the bore when the block is screwed home. In that position the bore is covered by the base of the block. A rotation of 180 degrees brings the opening in the block in line with the bore and the breech is open for loading.

Perhaps the most serious obstacle to securing rapid fire in the former type of field gun lay in the undoing of the pointer's work by the recoil; after every shot the gun had to be repointed. In modern field guns the carriage is anchored to the ground as firmly as possible and does not move. A pair of sliding ways controlled in position by the elevating and training gear but otherwise rigidly attached to the carriage is provided. The recoil takes place by the backward movement of the gun along these ways. This backward motion is restrained, partly by a spring but mainly by a hydraulic buffer which consumes most of the recoil energy, while that part stored in the spring serves to push the gun forward into firing position. These retraction springs, usually helical springs of steel, have proved a troublesome feature, and the greatest care in their manufacture has been essential for their successful performance. In the "seventy-fives" steel springs are replaced by compressed air. As the gun recoils the buffer fluid forces a free piston into an air-filled closed cylinder. The air so compressed pushes the gun into firing position, by its reversed action upon the piston after the recoil energy is consumed, and constitutes an ideal spring if leakage troubles can be overcome. The successful use of this device is one of the unique features of the gun. The recoil travel is 1.20 meters. Bearing in mind that in operation the barrel of the gun moves back and forth in a stationary slide, the sighting mechanism, which is attached to this member, is undisturbed.

The German field gun is of a model originally issued in 1896 and modified in 1906. In its modernized form it has an equipment practically similar to the French field piece, the difference being of design and dimensions. The barrel is 77 millimeters calibre and its length is

27.3 calibres. The breech is closed by a block, arranged to slide transversely to the bore, a method which is typical of the system in general use in German artillery. The recoil is absorbed by a hydraulic buffer in which a helical spring is used to return the gun to firing position.

A tabular comparison of the leading dimensions and performance of the two guns shows clearly to what extent they differ.

		French 75	German 77
Length of piece	meters	2.475	2.400
Maximum range	kilom.	6.500	5.300
Weight of projectile	kilogr.	7.200	6.850
Weight of charge	kilogr.	0.700	0.570
Weight per unit of section	kilogr.	163.	147.
Initial velocity	meters	529.	465.
Velocity at 1000 meters	meters	413.	369.
Velocity at 2000 meters	meters	334.	310.
Velocity at 3000 meters	meters	290.	275.
Muzzle energy	kg./m.	103.5	75.
Energy at 2000 meters	kg./m.	40.9	33.6
Number and weight of shrapnel balls		300 @ 12 gr.	200 @ 10 gr.
Danger zone for height of 1 meter:			
At 1000 meters	meters	41.	31.
At 2000 meters	meters	15.	12.
At 3000 meters	meters	7.6	6.5
Thickness of shield	millimeters	3.	5.
Weight of piece in action	kilogr.	1100.	950.
Weight of piece limber equipped	kilogr.	1950.	1850.

The Perception of Light of Short Duration. A. BONTARIC. (*Revue Scientifique,* vol. 54, No. 23, p. 720, November 25, December 2–9, 1916.)—Since 1911, extensive investigations of high academic interest and great practical value have been carried on by Blondel and Rey on the perception of a flash at the limit of visibility. The object of these researches was to determine the minimum illumination visible when the illumination is maintained during a variable but very brief period. According to previous researches by Bloch, the luminous impressions produced upon the retina by sources of varying intensities are equal when the sources act during periods inversely proportional to the illumination which they produce. According to this law, two sources are equivalent for the production of a minimum sensation when the product of illumination and its duration remains constant.

Blondel and Rey have shown that this law is applicable to intense and very brief sources. In the great majority of cases it is not in agreement with experiment. From a series of readings by a considerable number of subjects, they have found that the equation

$$Et = A + Bt$$

expresses the law between visible illumination and its duration, where E is the illumination, t, the time, and A and B constants. If t is infinite, that is if the illumination is steady, $A = E_0$, the least perceptible steady light. From a plot of the observations $A = 0.21\ E_0$ and

$$(E-E_0)\ t = 0.21\ E_0$$

From the practical point of view these results are of particular value in their application to lighthouse and other light projecting apparatus.

Development of the Optical Glass Industry. ANON. (*British Journal of Photography*, vol. lxii, No. 2949, p. 607. November 10, 1916.)—Though photography is not responsible for the introduction of optical glass, it affected its manufacture to a considerable extent, as it imposed special conditions that otherwise would not have been considered. The all-important distinction between optical and other ordinary glass is not merely one of composition, but one of quality as well; it must be homogeneous and free of striæ. The method of producing such glass was discovered about 1807 and its successful manufacture accomplished about 1814, Guinand, a Swiss, being credited with the first conception of the method, and Fraunhofer, a Bavarian, with the development of its application. Through Guinand's sons the secret of the method of manufacture found its way into France and eventually into England. The manufacture of optical glass in the former country began to be important about 1829 and in England (by Chance Brothers) about 1848, and those two countries rapidly obtained the lead in the industry.

Prior to the discovery of the right method of making optical glass, opticians had to be content with merely selecting the best samples of glass they could find from material made in the ordinary fashion, in consequence of which only small lenses could be produced. The discovery of the right method of manufacture enabled Fraunhofer to produce lenses of nearly 10 inches in diameter, whereas the further improvements made by Chance Brothers, in England, led to the production of 29-inch lenses in 1855. Just about the time when Fraunhofer succeeded in mastering the mechanical details of optical glass-making, he discovered a method of testing the optical qualities of glasses of different composition, and of expressing these qualities in figures. In 1804 Wollaston discovered the black lines in the color spectrum, which were afterward called Fraunhofer-lines. In 1814 Fraunhofer applied the spectroscopic method to the testing of the optical qualities of glass and promptly applied the results to the production and examination of new varieties. Up to that time only two varieties of glass were in use for optical purposes, crown and flint. With regard to the discovery that a combination of crown and flint lenses could be achromatic, Dolland is generally assumed to have been the originator in 1757, though Chester Morse Hall produced the first achromatic telescope in 1733, and there is evidence that the credit properly belongs to Hall. Out of this discovery eventually grew a demand for more varieties of glass, for with the simple crown and flint only a limited correction was possible. At first only the visible rays needed correction, and with the advent of photography the invisible rays required correction to secure a sharp photographic result. Color work has made further demands and practically requires that the lens be corrected for the whole of the visible spectrum. Fraunhofer having found means to test glass, set about this task, but his early death stopped further progress.

The deficiencies of flint and crown achromatic combinations were recognized, and numerous attempts were made to produce suitable glasses, but the difficulties and expense of the work handicapped and discouraged all experimenters on a small scale and little real progress was made. When Abbe and Schott, however, showed their willingness to undertake the work, at Jena, a liberal government enabled them to carry the matter through, and, as the result of a vast number of trials and tests, they produced glasses well adapted to the manufacture of achromatized lenses. The example of Schott was followed closely by Chance in England and Mantois in Paris, and at the present day optical glasses of great variety are obtainable. It should be noted that Fraunhofer should fairly receive the lion's share of credit due to those who have helped to develop optical glass. His early demise, only, in all probability prevented him from completing the results later achieved by others with virtually the same materials as were used by him in his early work.

The Cinematograph for Ordinary Portraiture. A. LOCKETT. (*The British Journal of Photography,* vol. lxiii, No. 2953, December 8, 1916.)—Frequenters of cinematograph theatres can hardly fail to notice the excellent examples of portraiture which occur in the film pictures. This is all the more remarkable, considering the enormous enlargement they have undergone on the screen and the impossibility of retouching. In spite of these disadvantages, the posing, lighting, modeling and expression—but particularly the latter—are often of a kind which could scarcely be surpassed by all the skill of the retoucher and finisher. It might be well worth the photographer's while to try a cinematograph camera occasionally for portraiture, if only for the added naturalness and vivacity gained by the sitter's lack of constraint, and the reassuring knowledge of absolute freedom of movement. There is, of course, no need to expose a large quantity of film. It is only necessary to turn the handle for a second or two, whenever a pleasing pose or expression is assumed, watching the sitter's movements in the finder. The resulting film negatives are critically examined, to select, say, the half-dozen best, and from these, enlargements or enlarged negatives can be made.

The cost of several feet of negative film compares favorably with that of the same number of half-plates. One foot of film, taking one second to expose and yielding sixteen pictures, costs about 2½d., while half-plates are at present 4 shillings per dozen. The time lost in elaborate posing, focussing, changing of slides, etc., is saved, and so also is retouching, except in the case of enlarged negatives where it is optional. The useful limit of enlargement is usually to post-card or cabinet size, the later being, roughly speaking, an enlargement of six diameters.

Secret Wireless Receiving. ANON. (*Electrical World,* vol. 68, No. 25, December 16, 1916.)—The idea of using small concealed aerials, whether of the ordinary open or closed magnetic loop types with extremely sensitive modern radio receiving instruments, seems to have occurred to a number of experimenters. In the laboratories of the U. S. Bureau of Standards such combinations have been developed to the extent that the reception of signals is possible from the powerful continuous-wave transmitters in Germany, 4000 miles away. When the loop aerial is used, it becomes feasible to determine the direction from which the signals are coming; with two loops at right angles, and a variable phase receiving transformer, rapid measurements of bearing can be made. At Union College there has also been some work done in the development of these small receiving aerials. Messages from stations all over the United States, according to report, have been received, and there is said to be less difficulty from atmospheric and other interference than when the usual tall aerial is used. Manifestly, if small wire arrangements located within doors can be used with equal effectiveness in place of the tall structures usually resorted to, considerable economies of installation and maintenance should result.

So far as has been disclosed, there is no radical change in the indoor aerials now under test as compared with those tried in the past years. The amount of energy abstracted from the passing electromagnetic wave is small when considered in its relation to the power which would be developed by the same wave in a high antenna-wire. In spite of its feebleness, however, the received impulse can now be utilized to produce an indication, because of the availability of recently developed vacuum-tube amplifiers. Signal effects so weak as to be entirely lost by the radio receivers of five years ago can now be built up to sufficient strength for easy telegraphing.

Vacuum relays are particularly suitable for use in conjunction with small receiving aerials, for the tiny absorbing systems are not subjected to the severe atmospheric impulses which play havoc with amplifying receivers as ordinarily used. Thus it is possible to take advantage of high powers of magnification, and to secure signals of commercial intensity without too much trouble from stray interference. Directive receiving tends to minimize the harmful effects of vagrant signals, and to some degree those of atmospherics. As a whole, the indoor antenna appears to be distinctly practical; and the opportunities it offers for concealment should make its use of marked military value.

New Chemical Industries in Southern California. A. W. KINNEY. (*Los Angeles Times,* December 17, 1916.)—The year 1916 has been the most notable year in the history of Southern California in the amount invested in chemical manufacturing enterprises and in the number of new products exploited. Millions of dollars have been expended in modern plants and more than twenty new products have been developed, samples of which are on display at the industrial bureau of the Chamber of Commerce. In view of the authoritative statement that in California there exists a wider diversity of the crude chemical materials of nature than in any similar area of the world, it is not strange that this section is playing a prominent part in the exploitation of new materials and is doing its full share in the upbuilding of American chemical industry.

During the year $1,500,000 has been invested in a powder plant at Chula Vista, below San Diego City proper. At the harbor district of Los Angeles five good-sized kelp products concerns have begun operations during the present year. After considerable investigation the Department of Agriculture has decided to locate at Summerland, Santa Barbara County, an experimental kelp products plant which will have a capacity of 200 tons of kelp per day. This institution will cost approximately $175,000, and will give the potash industry a thorough tryout. Two costly refineries have been erected at Searles Lake, San Bernardino County, and at Los Angeles Harbor. Potassium chloride is now being shipped from the Searles Lake plant. Other probable products from this and the harbor plant are caustic potash, permanganate of potash, bicarbonate of potash, borax, sodium carbonate, chloride and sulphate. Another large chemical enterprise is that the Solvay Process Company, which will handle similar products. Other sources of potash exploited during the year have been a Portland cement plant and the various beet-sugar factories.

At San Diego a plant has commenced operations devoted to the production of orcein dyes, using as raw material the orchilla weed, a moss found growing in vast quantities along the western coast of Lower California. It is claimed that these dyes can be produced cheaper than the imported article and are equal, if not superior, to it. Another company will engage in the manufacture of aniline dyes, utilizing the by-products of the local refineries and gas plants. Among other products now available are citric acid from cull lemons, strontium nitrate, chlorine, hydrated lime, and molybdenum and tungsten compounds. This has indeed been a most remarkable year in chemical development, and adequate research work should result in converting the great variety of raw material available into commodities that will eventually yield very large returns to the region.

The Manufacture of Linoleum. E. S. WIARD. (*Metallurgical and Chemical Engineering,* vol. xv, No. 12, December 15, 1916.)—The process of making linoleum, the familiar water-proof floor covering, was invented by Frederick Walton in England in 1860 and the product was first brought out under the name Kamptulicon, but later received the name Linoleum. The foundation of linoleum is jute burlap. This is coated with the very best grade of finely ground cork bonded with a water-proof material. For the bonding material, linseed or other drying oils are used, these being oils which on exposure to the air will absorb sufficient oxygen to form a solid resinous mass. The linseed oil must be of good quality. The oil is first boiled, as in paint making, and the process of drying is facilitated by adding a small quantity of oxide of lead. From the boiling tanks the oil passes to pieces of light cotton fabric, known as scrim, which hang vertically from iron bars. The oil is poured over the scrim and what adheres to the surface at a temperature of about 100° F. becomes hardened. The operation is repeated from time to time until there is a coating on the scrim of sufficient thickness, when it is cut down and ground between rollers. The usual thickness of the skin on the scrim is one-half inch. The ground oil is then mixed with resin and kauri gum until the whole mass is homogeneous and forms the bonding cement.

The cement and cork are then mixed together, and if the linoleum is to be plain, the coloring matter is added at this stage. The mixture is then rolled into the jute backing, there being two cylinders to effect this operation and to secure evenness of the layer. The printing of the design is done mechanically by rising and falling color blocks. The movement of the linoleum under the printing blocks is continuous. In the manufacture of inlaid linoleum the mixture of cement and cork is compressed into sheets of different colors which are afterwards cut up into the components of the design and are affixed to the burlap by pressure. In another process the linoleum mixture in the form of a powder is dropped upon the jute in a way to form the design and is then subjected to heavy pressure to fix it and secure a permanent contact with the backing.

Storage of Energy. G. P. PEARCE. (*Machinery* (N. Y.), vol. 23, No. 3, November, 1916.)—In physical problems, the storage and release of energy plays a most important part and the success or failure of many a mechanical device is governed by the space or weight entailed in providing an adequate supply of energy for its operation and by the degree of complication of the apparatus employed for its control. The methods available may be classified into four general divisions. (1) Those employing the elasticity of materials; (2) those employing chemical reactions to generate heat or electricity; (3) those employing kinetic energy, and (4) those operated by the action of gravity.

Where relatively small amounts of energy are required, springs in various forms have proved simple and effective for the purpose, as in time-pieces and small mechanisms for intermittent use. The amount of energy that can be stored per pound varies with the type of spring. The "screen door" torsion spring will absorb 46 foot-pounds of energy, while the helical spring will store 88 foot-pounds. Of late years large flat spiral (clock) springs have been successfully employed in automobile "self-starters." For less important work rubber has given good results. Years before Professor Langley made his flying machine, a Frenchman made simple toys, which were driven by twisted elastic bands, that would fly 50 feet or more. These simple toys could fly because it is possible to store considerable energy in rubber; in fact, it is superior to the finest tempered steel spring in this respect, for almost 3000 foot-pounds per pound can be absorbed and delivered.

Ordinary air when highly compressed, say around 2000 pounds per square inch, is capable of delivering 50,000 foot-pounds per pound. Steam is even better, and will deliver 240,000 foot-pounds when expanded from 250 down to 2 pounds per square inch absolute. These figures are, however, not comparable with those for steel and rubber when the weight of the containing and transmitting apparatus is considered.

The flywheel is generally looked upon as an ideal device for the storage of power, but a cast-iron wheel reaches its limit at about 640 foot-pounds per pound. A steel flywheel gives better results and will yield about 3200 foot-pounds. The energy of ordinary flywheels sinks into insignificance, though, when compared with that stored in the rim of a De Laval steam turbine disc where it may reach 31,000 foot-pounds. The most efficient electric storage batteries cannot equal this, as they reach their limit at approximately 22,000 to 30,000 foot-pounds per pound and many commercial batteries on the market do not exceed 3200 foot-pounds.

Power Loss in Screw Propellers Due to Rough Surface. ANON. (*Engineering News*, vol. 76, No. 25, December 21, 1916.)—Experiments described in a paper by Naval Constructor William McEntee, U. S. N., at the recent annual meeting of the Society of Naval Architects and Marine Engineers indicate that a great saving of power is effected when ship propellers are made of some non-corrodible metal like bronze and are carefully machined and polished, as compared with the common practice of using propeller castings as they come from the foundry. It is likely that these experiments teach a valuable lesson, also, to the designers and builders of centrifugal pumps. The skin friction of a rapidly moving impeller in a centrifugal pump must be very great, especially in pumps working at high heads; and it seems all but certain that this skin friction must be greatly increased if the impeller is a rough casting.

Usually screw propellers used on naval vessels are carefully finished by machining the rear surface of the blade to a true helicoidal surface and finishing by hand the front face so that it will be perfectly smooth. The propellers of merchant vessels, however, generally have blades of cast iron or cast steel and are given no finish whatever, except trimming off the rough places with chisel or file. In addition, as is well known, iron and steel propellers often suffer by pitting, so that they present an extremely rough surface to the water.

With the object of determining the relative efficiency of a smooth finished propeller and a propeller left with the rough surfaces of the original casting, four propellers, 16 inches in diameter, were tested at a uniform speed of 5 knots. Two of the propellers were of bronze, one of cast iron and one of cast steel. One of the bronze propellers was finished perfectly smooth; the others were left as they came from the mold, with only the ordinary cleaning. The test showed that the propellers with a rough surface had a maximum efficiency of about 63 per cent. whereas the polished propeller had an efficiency of about 72 per cent. Another test was made to determine the effect of a still rougher surface, such as exists on a propeller that becomes badly pitted or on which barnacles and other sea growths accumulate, by varnishing the polished bronze propeller and applying to the sticky varnish a layer of granulated cork, such as is used for cork paint in ship work. The efficiency of the artificially roughened propeller which had been about 72 per cent. in its polished condition was reduced to 36 per cent.

A Rapid Process for Determining the Acidity of Corn. (*U. S. Department of Agriculture.* Circular 68.)—The test to determine the acidity of corn, which previously required 16 to 18 hours, can be made in less than one hour by the use of improved apparatus developed by H. J. Besly and G. H. Baston of the office of Grain Standardization, Bureau of Plant Industry. Under the new method an electric mechanism, similar to those seen on soda fountains, is used to mix finely ground corn and alcohol. Thirty minutes of mixing, it is found, will extract from the corn an amount of acid-reacting substances comparable to the amount extracted through digestion in 86 per cent. alcohol at room temperature for 18 hours.

The methods for making acidity determinations of corn with this apparatus are described in detail in circular 68, Office of the Secretary, recently published by the U. S. Department of Agriculture.

French National Laboratory of Physics and Mechanics. ANON. (*Metallurgical and Chemical Engineering,* vol. xvi, No. 4, p. 186, February 15, 1917.)—The Academie des Sciences, according to the *Genie Civil,* has resolved to establish a national physical and mechanical laboratory for the purpose of scientific research directed toward industrial uses. The laboratory will be controlled by a council, of which half the members will be nominated by the Academy, one-fourth by the State Department, and the remainder by the chief industrial associations. The executive control will be in the hands of a small technical committee. Existing laboratories engaged in similar work will be affiliated to the National Laboratory, and will work in close relationship to the latter. Substantial funds will have to be provided for the working expenses of the laboratory and for the assistance of the affiliated institutions.

Manganese Steel Castings. W. S. McKee. (*The Iron Trade Review,* vol. lx, No. 7, p. 413, February 15, 1917.)—Manganese steel was developed originally in England, largely through the efforts of Sir Robert Hadfield. It has been manufactured on a commercial scale for nearly 26 years. The first manganese steel castings made in the United States were turned out in 1892. Originally it was considered impossible to make manganese steel castings successfully weighing over a few hundred pounds, but at the present time large rolling-mill pinions, crusher heads, and similar castings weighing up to 30,000 pounds each are being produced regularly, and it does not appear that the limit of weight has been reached by a considerable margin.

As manufactured at present, manganese steel is similar in analysis to ordinary converter metal, except that it is high in carbon and unusually high in manganese. In ordinary commercial castings the proportions of the latter metal range from 11 to 13½ per cent. This combination of constituents gives the finished castings certain distinctive physical properties. Heat treatment is a very essential part of the process. The necessity for heat treatment limits the thickness of section which it is possible to cast successfully. Originally the castings were made with comparatively thin sections, but researches during the past few years have made it possible to increase the thickness of section, so that at present castings with walls up to 5½ inches in thickness are handled satisfactorily. Manganese steel made by Robert W. Hunt & Co., Chicago, has an elastic limit of 53,400 pounds, tensile strength of 108,400 pounds per square inch, an elongation of 33.7 per cent. in 2 inches, and a reduction in area of 38.6 per cent. This steel does not owe its wear-resisting qualities to its hardness. When subjected to the Brinell test, it shows an average hardness number of 200. The electrical resistance of manganese steel is about 3.4 times that of ordinary Bessemer steel. It is non-magnetic, and advantage is taken of this property in the use of this material for shields or bottom plates of lifting magnets.

If the castings require finishing, special equipment is necessary. Ordinary machining methods are unsuccessful, and grinding must be employed. Holes more than ¼ inch in diameter are cored and ground to size. When it is necessary to drill smaller holes or to cut threads, soft steel or wrought-iron inserts are set in the molds at desired points like chaplets and the metal is cast around them.

Effect of Centrifugal Force on Colloidal Solutions. E. E. AYRES, JR. (*Metallurgical and Chemical Engineering,* vol. xvi, No. 4, p. 190, February 15, 1917.)—Particles of a uniform size suspended in a liquid medium will settle by gravity when the product of their masses in grammes by the constant 3×10^{16} is as large as 10. When the product is less than 10, a partial subsidence will occur until an equilibrium is established. The only considerable force opposing complete subsidence in this case is osmotic pressure. By the use of a law of distribution which takes into account the opposing forces, it is possible to compute the concentration at any level when the system is at equilibrium. When the conditions are such that a particle will not settle completely by gravity, it is possible to cause complete subsidence by the application of centrifugal force when the product of the mass in grammes, the force in dynes, and the constant 3×10^{16} is greater than 10. Here, again, a partial subsidence with the establishment of an equilibrium will occur when the product is less than 10. The time required to establish this equilibrium can be computed from a modification of Stokes's law for velocity.

The highest commercial centrifugal force, 40,000 times gravity, can completely remove particles as small as the lower limit of ultramicroscopic observation, but such a separation will require 33 hours when the liquid medium is water. For less viscous media the time will be shortened. Smaller particles can never be separated by this force. Particles just too small to be retained by a fine porcelain filter can be removed in a few seconds. Gases at different densities cannot be completely separated by any force less than about 100,000,000 times gravity. The same applies to true solutions. But gases should be partially separated by a much lower force within a reasonable time, whereas solutions in liquid media would require several weeks.

Corona and Rectification in Hydrogen. J. W. DAVIS and C. S. BREESE. (*Proceedings of the American Institute of Electrical Engineers,* vol. xxxvi, No. 2, p. 143, February, 1917.)—When a sufficiently high potential difference is impressed between two parallel wires, or a wire and concentric cylinder, separated by air or some other gas, this gas, which for low potential gradients is a very good insulator, breaks down and becomes a partial conductor. The phenomena connected with this character of conduction through gases are known collectively by the name corona. The failure of the gaseous dielectric separating the metallic conductors is made evident by a flow of current from one conductor to the other, by a power loss, and, in practically all cases, by the appearance of light at either one or both of the conductor surfaces. In some cases light appears in the intervening space. Since the present theories as to the mechanism of corona formation do not satisfactorily account for all of the observed phenomena, it was decided to carry out further investigations in the hope that, when enough data were accumulated, some theory based on fundamental principles explaining the observed phenomena might be evolved.

Both direct and alternating electromotive forces were used, and the characteristic behavior of the corona was given by means of curves, photographs, and oscillograms. The corona discharge in hydrogen was found to differ from that in air in the following particulars: The discharge from a negative wire was found to differ widely from a positive wire in the magnitude of the voltage necessary to start the discharge in the shape of a volt-ampère characteristic and also in the stability of the discharge. Corona in hydrogen between concentric cylinders is shown to be a practicable method for rectifying high potential alternating currents.

Internal Temperature of A. C. Generators. R. KELLY. (*Proceedings of the American Institute of Electrical Engineers,* vol. xxxvi, No. 2, p. 119, February, 1917.)—The results of tests of a number of typical large A. C. generators show that there is a wide divergence between internal and surface temperatures in A. C. generator stators, the internal temperature being measured by a thermocouple placed between armature coils in the same slot and in the centre of the core. The difference between these measured internal temperatures and the corresponding surface temperatures in the tests varies from 0° to 35.5° C. This wide divergence is explained by the aid of the tests and of calculations. A method of calculation for internal temperatures is given which is based on simple heat laws and on data obtained from many tests. By means of the tests and of parallel calculations, the effect on the internal temperature of changes of frequency, core length, thickness and quality of insulation, armature current densities and core densities is explained. The capacity of the end windings to dissipate heat is also discussed. In conclusion, it is stated that, although the wide divergence between surface and internal temperatures of different classes is regular and can be justified, yet it is plain that there is no one average figure that can be used for that difference for all classes of A. C. generators.

Casting High-speed Steel Tools to Shape. ANON. (*American Machinist,* vol. xxxxvi, No. 7, p. 285, February 15, 1917.)—It is a commonly-accepted idea that metal-cutting tools—lathe or planer tools, milling cutters, and the like—have to be made from bar stock or special forgings. To think that tools of this class can be made in practically the same manner as common castings is a decided departure from established precepts, especially when these tools are of high-speed steel. However, Anton Boerder, some time ago, invented a process by which high-speed metal-cutting tools of all kinds can be cast to shape, leaving from one-sixteenth to one-eighth of an inch for finishing. Tools of this kind are now being cast by the High-speed Tools Corporation, Toledo, Ohio. From reliable sources it is reported that these tools compare favorably in edge-holding qualities with forged or bar machined stock, and that it may be forged into various shapes when necessary. The large saving in time and material in finish-machining such tools is at once apparent to any practical shopman. This company also casts bars and billets for various purposes.

The company does not machine the tools, but supplies them to shops as ordered, just enough extra metal being allowed to clean up well and give a good edge where needed. The tools are cast from patterns exactly as if pouring from cast iron, and, after being cleaned and carefully annealed, are ready for delivery. The heat treatment recommended is as follows: Bring the steel slowly to 650° F., raise to 1200, then raise quickly to 2250 and quench in fish oil until cool. If a gas furnace is used, supply more gas than air in order to prevent the steel from acquiring a soft cutting edge.

Oscillating-current Circuits by the Method of Generalized Angular Velocities. V. BUSH. (*Proceedings of the American Institute of Electrical Engineers,* vol. xxxvi, No. 2, p. 189, February, 1917.)—The oscillating-current circuit differs from the alternating-current circuit in that the sinusoids involved are damped. In the same way that alternating-current theorems are obtained by generalized direct-current theorems, it is possible to obtain oscillating-current theorems by still further generalization. This involves a generalized angular velocity and a generalized impedance which are complex quantities. Kirchoff's law thus generalized yields a simple method of determining the generalized angular velocities, and thus the frequencies and decrements, of free oscillation.

In an oscillating-current circuit, there being no impressed voltage, the initial voltage present in the circuit must be used in determining the amplitudes of oscillation. This results in the introduction of a "threshold impedance" for use in determining the amplitudes, which is obtained by a single differentiation from the generalized impedance. Further direct-current rules may also be readily generalized for convenient use in the solution of oscillating-current circuits. A simple example is given to show the method of procedure. The discharge of a leaky condenser through a reactor furnishes a second example which better illustrates the convenience of the method for numerical computations. As a third example, the oscillation of a three-section artificial cable under particular terminal conditions is chosen.

Progress in Aërial Navigation. SANTOS-DUMONT. (*Flying,* vol. vi, No. 1, p. 31, February, 1917.)—On the 14th of July, 1903, the author piloted a dirigible at the Longchamps military manœuvres in which 100,000 troops took part. That was the first time aërial navigation was a feature of a military demonstration. At that time it was predicted that aërial warfare would be one of the most important phases of future military campaigns. The prediction was scoffed at and resented by militarists, who could not see the airships in any light but as a childish toy. The present war, however, has demonstrated that aëronautics has revolutionized warfare; aircraft are now employed in every branch of military service.

Less than a decade ago the author's aëroplane was considered a marvel. In this machine, in which there was place for only one person, a motor of about twenty horsepower was used. At first, flights of only a few metres could be made. Only enough gasoline to fly three-quarters of an hour could be carried, and the longest flight was twelve miles. To-day machines are being made with engines of 1000 horsepower, capable of carrying thirty passengers nearly 1000 miles without landing. A large factory in the United States turns out twelve aëroplanes daily. Among the aëroplanes constructed, there is one capable of flying over 600 miles and carrying thirty persons. An aëroplane of this type, equipped with four motors totalling over 1000 horsepower, has flown in England with eight passengers and 600 gallons of gasoline and other equipment on board at a speed of 75 miles per hour. This machine is built with three planes spreading 133 feet, with a length of 68 feet, and its total weight is over ten tons. The chief problem which confronted aërial navigation—securing an efficient motor—may be considered solved; the aëroplane motor of to-day is more reliable than the automobile motor was ten years ago.

The Sterilization of Beer by Filtration. E. ZAHM. (*Pure Products,* vol. xiii, No. 2, p. 57, February, 1917.)—A liquid is sterile when it has been freed from microörganisms or the microörganisms therein contained have been deprived of the power of reproduction. In the brewery, beer, before it is filled into the containers in which it is marketed, is subjected to filtration through layers of pulp, so that it is in a state of brilliancy. This beer, nevertheless, contains some microörganisms which have not been removed in the filtering process and, at the warmer temperatures which obtain in beer while marketing, multiply and cause disturbances in the stability of the product. To prevent this fermentation, the process of pasteurization has been generally used, whereby the yeast and other microörganisms have been deprived of the power of reproduction. This process, though it prevents further fermentation, produces undesirable changes in the taste and character of the beer, so that it is generally conceded that a pasteurized beer is inferior to the same product before treatment.

In the process of brewing, a hopped wort is subjected to fermentation through the introduction of yeast. With this yeast are introduced enzymes which are formed during the process of fermentation, which are present in the beer when it is filled into the containers. Thus beer is not merely a solution of extract matter, alcohol, and carbonic acid, but contains enzymes which have a beneficial action on the digestive functions in the human body. The process of pasteurization arrests or destroys the action of these enzymes as well as that of the microörganisms, with the result that the beers so treated have not only altered in taste, but also lack that enzymatic action which is desirable in beer as a food product. It is therefore readily understood that if beer can be brought to a sterile state in the bottle and marketed with its enzymatic power unimpaired, a superior product is assured.

Filtration to sterility produces such results. That liquids can be filtered to sterility has been known for many years, and the process has been generally used in the treatment of serums and other liquids in the laboratory. A filter of the type generally used in breweries, in which the filtering medium consists of layers of fibrous pulp, is not adaptable to sterile filtration. This is not because the interstices of pulp mass are not minute enough to withhold the passage of the microörganisms, but because, under pressure fluctuations, the interstices change in form and size, permitting some of the microörganisms to pass. Both the porcelain and clay tube filters are impracticable because of their limited capacity. The filtering properties of diatomaceous or infusorial earth are far superior to other known substances adaptable to filtration, and were adopted as most satisfactory for the purpose. An apparatus equipped with a battery of 110 cylinders of this material, two inches in diameter and about a foot long, has a capacity of fifty pint bottles per minute.

Formation of Clinkers in Boiler Furnaces. A. A. CARY. (*Electrical World,* vol. lxix, No. 6, p. 267, February 10, 1917.)—During many years' experience in designing, testing, improving, and operating furnaces, used for many purposes, no branch of this subject has been found that requires more consideration than the troublesome formation of clinkers in the furnace and the formation and growth of clinkers on furnace linings. In a great majority of cases, this trouble can be either greatly reduced or avoided, for clinkers are formed by the fusion of the ash and refuse which remain after the combustion of the coal in the furnace. Ash is really a very useful material in the furnace when it is properly taken care of there; since, with proper thickness of ash covering the top surface of the grate, the burning and warping of the bars are prevented.

Where properly designed shaking bars are used, the thickness of the ash-bed on the top surface of the bars can be easily regulated, and it is very necessary that this be properly accomplished with this type of bar, as most of the shaking grates are designed with thin, delicate edges which are easily burned or warped when brought into contact with a hot fire-bed. It is quite essential that the thickness of the ash-bed should always be reduced before any attempt is made to break up the fire-bed above, otherwise the ash will be thrown up into the bed of fuel and fused into clinker. The shaking grate, improperly used, may be productive of more clinker in the furnace than would occur with the plain stationary grate in use. The thickness and conditions of the fire-bed have much to do with this grate and clinker trouble, however. The density of the fuel bed is really of more importance than its thickness. A comparatively thin fire-bed that is dense and compact will hold the ash within its hot body, instead of allowing it to precipitate to the grate bars, just as much as a thicker bed when it is more open and porous.

When any fire-bed is more or less solid or compact, the air for its combustion will not pass uniformly throughout its mass, but, on the contrary, this air will search out its easiest paths of passage and flow through the irregularly scattered openings formed by cracks or holes in the fire-bed, and, with the ash held up in this densely-packed bed, the air, rushing through these selected positions, will cause intense combustion to occur at such places, which rapidly fuses the surrounding ash into clinker and at the same time causes the soft, pasty mass to attach itself to a considerable amount of solid combustible fuel. Too thin fires carried on the grates should be avoided, especially with shaking grates, as every fire-bed should be of sufficient depth of ash to be carried on the bars to protect them from the intense heat of the burning fuel above them. Excepting these very thin fire-beds, it may be said that the intensity of draft required to operate a furnace is, generally speaking, a measure of its clinker-making properties, which is another way of saying that the intensity of the draft required is a measure of the density of the fire-bed.

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BY-PRODUCT COKE AND COKING OPERATIONS.*

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THERE has been so much written and published bearing on the surprisingly large development in the building of by-product coke ovens that it seems unnecessary further to emphasize this point in detail. Suffice it to say, that on January 1, 1915, there were in operation 6438 by-product recovery ovens of various sizes in the United States and Canada, having a capacity to carbonize 24,000,000 tons of coal per annum, and to produce therefrom approximately 18,800,000 tons of coke. Despite the fact that in the interim practically five hundred ovens have been discarded, on January 1, 1918, there will be in operation, if present contracts are completed, 9900 ovens, having a capacity to carbonize 47,400,000 tons per annum, giving a coke production of 35,000,000 tons. In this three-year period by-product coke production will have practically doubled, and there will have been as much gain in capacity as in the previous twenty years.

The cause of this rapid increase has not been a desire to take

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* Presented by Mr. Ramsburg at a joint meeting of the Mechanical and Engineering Section and the American Society of Mechanical Engineers, held Thursday, February 1, 1917.

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advantage of the inflated prices for by-products due to war conditions, but a financial condition favoring large investments brought about by the war, and making it possible to carry forward plans made previously for such development when opportunity presented. That many of the plants have been completed and put into operation at a time when they might take advantage of the high prices for tar, ammonia, and benzols is a fortunate coincident and not a contributory cause.

While one is much impressed by the amount of money saved from the recovery of these by-products and by the stimulus given to the chemical and manufacturing industries by the supply of such an abundance of raw materials, the most impressive fact is the conservation of our coal supply brought about by the introduction of modern methods. It may be of interest to put aside, for the moment, the question of profits obtainable from the sale of ammonium sulphate and other by-products as materials of chemical industry and to make a few calculations simply from the standpoint of *fuel values*. To put the matter on the most conservative basis possible, let us figure such values in terms of coal.

Table I (p. 393) shows the fundamentals of the matter from this standpoint.

This table shows a total fuel saving of 825 pounds of coal per ton of furnace coke. Please note in this that the fuel value of the gas is put not at its value compared with the coal necessary to replace it with producer gas, which is necessarily made at a low efficiency, but as against raw *coal*, B. T. U. for B. T. U. There is a further saving in the blast furnace. Reports from a large number of blast furnace plants indicate that a saving of 200 pounds of coke per ton of beehive coke formerly used is a conservative average figure. Figured back on a coal basis, these 200 pounds of coke represent 282½ pounds of coal at the beehive oven, so that the total saving amounts to approximately 1100 pounds of coal—0.55 ton—for each ton of by-product coke made in the modern plant.

Since the ovens gained in operation from January 1, 1915, to 1918 will produce practically 16,200,000 tons of coke per annum, it follows that these ovens will save annually to this country the fuel equivalent of 9,000,000 tons of coal. While it is true that the total coal resources of America have up to this time hardly been scratched, nevertheless it is important to emphasize that this saving is taking place in low ash, low sulphur, high-grade coking coal—coal which, from its mining locations, naturally carries the most favorable freight and labor conditions, and as such is of vast importance—to us and to posterity.

Looking backward over the years consumed in bringing the coke oven to its present stage of development in America, there are a number of events and conditions which stand out preeminently and may be considered as the high spots in progress. The first of these dates back to 1906. In that year the United States Steel Corporation was brought face to face with the necessity of formulating a definite policy as to its coke supply, and, in preparation, appointed a committee of its leading engineers and works managers, whose object was to study beehive coking and by-

Table I.

By-product Yields from Coal Such as Now Used to Make First-class By-product Coke in the Middle States District. 85 per cent. High Volatile, 15 per cent. Low Volatile.

		Fuel value equivalent, pounds of coal.
To make 1 Ton Furnace Coke. *1.4—1.5 Tons Coal Required. By beehive coking, the by-products wasted have a heat value equivalent to 625 pounds of coal. At least 200 additional pounds of coal are wasted in the process of beehive coking by combustion.*	*Surplus Gas.* *9000 cubic feet, 550 B. T. U.* *Used as fuel.*	350
	Tar. *12 gallons.* Used to make creosote oil, pitch, lampblack, various oils and dye materials.	133
	Ammonium Sulphate. *33 pounds* (or, in form of 25 per cent. ammonia liquor, *33* pounds). Used for fertilizer, for refrigeration, and for nitric acid and other chemical manufactures.	(*No fuel equivalent*)
	Benzols (as light oil). *4.5 gallons.* Used for motor fuel, dye material base, phenol and other chemical manufacture, solvent and cleanser	42
	Coke Breeze. *120 pounds* Used as fuel.	100
	Total	625
Add coal equivalent wasted in beehive oven		200
Total economy of by-product oven per ton coke		825

product coking and to make a recommendation to the company as to the course to pursue after a comprehensive study of the whole matter. This committee did not restrict its investigations to America, but spent a long period in England, Germany, and Austria, studying with great care and attention to detail the most minute phases of the various processes submitted for consideration. It has been said that the report of this committee, which was headed by Mr. G. G. Crawford, now president of the Tennessee Coal, Iron and Railroad Company, was one of the finest and most complete reports ever presented on an engineering and general technical subject.

The advice of this committee was quickly acted upon by the Corporation in the decision to build a by-product oven plant at Joliet, Ill., in connection with the blast furnace and steel plant of the Illinois Steel Company, and to build that type of oven which they had found to be giving the most efficient results in the European countries.

The success of this Joliet plant was so immediate, not only from a standpoint of economy of coke manufacturing, but in the increased blast furnace capacity and efficiency, that the Corporation without delay proceeded with the construction of additional plants of the same type, including the largest by-product coke plant in the world at Gary, Ind., consisting of 560 Koppers ovens, and a plant of approximately the same size as the Joliet plant (280 ovens) at Ensley, Ala., for the Tennessee Coal, Iron and Railroad Company.

The second high spot was the selection of silica material for one of the oven batteries at Joliet.

While some silica had been used on other types of ovens previous to this time, the use of it in the ovens of the Koppers type, with their inherent qualities of uniform heating due to their *basic heating principles,* intensified the value of this type of oven enormously, and put a new aspect on the entire coke situation. The value of the silica in this connection is due to four characteristics.

First.—The conductivity at high temperatures is superior to that of clay brick.

Second.—The fusing or softening temperature is much higher than that of fire clay.

Third.—The action under heat may be calculated with scientific exactness, due to its practically constant composition.

Fourth.—The expansion and contraction of silica material between 2000° F. and 2600° F. is practically negligible, so that when the material has once been heated to within this temperature range (under which condition the coking operations are conducted) no further appreciable movement takes place.

The Koppers oven is designed to utilize all of these characteristics to great advantage. From the time that the silica battery (one of four) was first built at Joliet, Ill., no Koppers oven has been built in America of any other material.

The third high spot might be better represented by some other simile, since it was more gradual in its development. It consisted in a realization that with uniform heat distribution in the ovens and with the use of silica material much higher heats and consequent higher coking velocities could be employed, and, further, that, with the lower coking periods, higher volatile coals could be used, with increased yields of by-products and equally satisfactory coke.

The result can be demonstrated by the fact that the Joliet plant of the United States Steel Corporation, put into operation in 1908, was originally planned to use from 70 to 80 per cent. of low volatile coal, and the coking time was figured at 24 hours. The Koppers Company is now building at Clairton, Pa., near Pittsburgh, a coke plant for the Steel Corporation of 640 ovens, and the plant is so designed that it may be operated on 15 hours' coking time and is expected to use 100 per cent. high volatile coal. Even if the 100 per cent. high volatile coal proves not to make quite as high grade furnace coke as the coke at Joliet, its use will work out on broad lines to better purpose and time will tell where the comparison lies, after opportunity has been given the furnace operators to adjust themselves to the new type of coke.

The effect on the products can best be shown by reference to Table II.

Table II.

YIELDS OF BY-PRODUCTS PER TON COKE.

	Coal Mixture A. 80 per cent. low volatile. 20 per cent. high volatile.	*Coal Mixture B.* 100 per cent. high volatile.
Tar	6.5 gallon.	13.5 gallons.
Ammonium sulphate	23.3 pounds.	38.0 pounds.
Surplus gas (debenzolized)	7500 cubic feet.	10,000 cubic feet.
B. T. U. per cubic foot gas	500	560
Total B. T. U.'s in surplus gas	3,750,000	5,600,000
Light oil (benzols)	2.6 gallons.	5.4 gallons.

A comparison in value of by-products on a basis of normal values shows a credit per ton of furnace coke of approximately $1.25 in favor of the high volatile coal.

The fourth high spot in development was the awakening to the fact that, while an increase in the cubical content of an oven tends to a reduction in plant cost and in operating labor due to handling larger units, a decrease in oven width would more than offset this unit size advantage because of absolutely different conditions.

The reason for this becomes apparent with an understanding of the factors involved. Increased length of oven gives increased cubical content, and the ultimate economic length depends on the mechanical and structural limits. Of increased height the same may be said, except that this involves questions of time of contact of volatile products and speed of their flow which modify the advantage and which are yet to be finally worked out.

Increased *oven width* involves an entirely different consideration. Practically all the heat supplied for the coking of the coal mass flows from the two walls toward the centre. This flow of heat depends, to a large extent, on the resistance and temperature, and in the coke oven the average rate of coking depends, of course, on the rate of heat penetration. For example, it becomes apparent at once, in a comparison between a 16-inch oven and a 20-inch oven, that the following is true:

(*a*) With the same temperature of wall the average velocity of coking in the 20-inch oven will be less than in the 16-inch oven, and the time required to coke the 20-inch oven will be more than proportionally greater than the 16-inch oven.

(*b*) To coke the 20-inch oven in the same time as the 16-inch oven, the wall temperature must be increased very markedly.

(*c*) To coke the coal in the two ovens at the same average rate, the wall of the wider oven must be considerably hotter than the narrower one.

(*d*) With the *same wall temperatures*, more coke can be made per day in the narrower oven than in the wide one.

(*e*) To make the same amount of coke per day, the wall temperature in the 16-inch oven would be lower.

Four points are of great value in this connection:

1. Overcoked material is of less value in a furnace than a greener coke.

2. The wider the oven the more overcoked the outside layers will be and the larger the proportion of overcoked material for a given output.

3. The production of by-products is enhanced by reducing the wall temperatures.

4. The life of oven brickwork is increased by being operated at lower temperatures.

The result of this reasoning was the decision, in 1914, to reduce the width of oven from 19¾ inches, average then being built, to 18¼ inches.

Plants of the reduced width are now in operation as follows:

	Ovens
Toledo Furnace Company	94
Youngstown Sheet and Tube Company	204
United Furnace Company	47
River Furnace Company	204

There is no doubt among those who have been acquainted with the wider ovens that the narrower oven has the following distinct advantages:

1. Less sponge in the coke.
2. Better coke from the same coal.
3. As good coke from higher volatile mixtures.
4. Higher yields of tar, ammonia, and benzols.
5. Low temperatures for the same coking velocity.

We shall now consider the fifth high spot in coke oven development; namely, the universal recovery of benzols. This may be laid almost entirely to the war, but partly to the increasing demand for motor fuel. It was the war which furnished the primary inducement to developing this phase of the industry; but the fact that the material might be disposed of advantageously for motor fuel after the demand for explosives would cease had an important bearing in stabilizing the large investments demanded.

Previous to the war comparatively few plants were equipped for benzol recovery; in fact, outside the plants of the Semet Solvay Company, operated for their own account, there was comparatively little benzol extracted, and this was used, for the most part, in enriching illuminating gas. To-day practically every coke oven plant in America has installed this recovery, and the production in 1917 will be in excess of 40,000,000 gallons, rated as light oil, if continued at the present rate.

While the removal of benzol reduces the heat units in the gas, the loss in this manner is a very small factor, and the return to be secured from the sale of this product is likely to be greater than that secured from the recovery of tar.

One feature of the benzol credit as related to motor fuel is the smallness of the quantity compared with gasoline production, and, since benzol and gasoline are miscible, the utility of benzol will be enhanced by increasing the quantities available.

Experiments recently conducted by a large oil company on its trucks and passenger automobiles proved that not only is benzol more valuable than gasoline as a motor fuel when used straight, but its effective value is increased by being mixed with gasoline. While these experiments are not complete, nevertheless they indicate that a mixture of equal parts of gasoline and benzol gives a value over 16 per cent. greater than that of straight gasoline, which shows 32 per cent. increased value for the benzol half. In 1917 there will be produced in this country over 1,000,000,000 gallons of gasoline, so, while the value of benzol is stabilized, for this reason it cannot be a very great factor in the motor fuel situation. Every means should be taken not only to secure additional quantities from a standpoint of *preparedness,* but from a standpoint of motor fuel supply.

In connection with the value of benzol as a motor fuel there is an interesting fact which may in the future have a very marked influence.

Alcohol is in many quarters looked upon as the ultimate fuel, but it cannot be employed except with less efficiency and with greater difficulties, due to its high hydrogen content. Commercial alcohol and gasoline are not miscible. Alcohol and benzol are miscible and make a most efficient fuel, and, further, *after the addition of benzol to alcohol* the mixture will carry quite a high proportion of gasoline. The future may see benzol as the tie between gasoline and alcohol, permitting a piecing out of the gasoline supply and an introduction of alcohol as a commercial motor fuel.

So much for the introduction of benzol recovery into all coke plants, and for the salient points in coke oven development in America.

We shall now take up a somewhat more detailed study of by-product coke and its use in blast furnaces.

The phenomenal growth of the by-product industry has stimulated a renewed interest in the main product. This interest is due, first, to the recent revolutionizing of ideas regarding the relative values of by-product and beehive coke. The tardy recognition of the fact that by-product coke of a fairly wide range of origin, when properly used in the blast furnace, gives results not merely as good as, but much *superior* to, those obtained from beehive coke, was accompanied by a realization that the limit of efficiency had by no means been reached; that Grüner's "ideal performance"—long the *ne plus ultra* of blast furnace men—was actually being surpassed by many blast furnaces, and that much regarding the question of coke economy still remained to be learned. In the renewed study of the subject that this realization is just beginning to stimulate, we have the inestimable advantage that the by-product coke plants are being located in proximity to, and usually under the same management as, the blast furnaces that they are intended to supply, instead of being placed at the coal mines, long distances away, as was the case with the beehive ovens. Thus the blast furnace operator knows better the sources of the material that he has to use and the conditions under which it was produced, while the coke plant operator can more intelligently regulate the performance of his ovens and the quality of his product, according to the requirements of the furnace. Above all, the combination and coöperation of the two plants result in a regularity of performance that is perhaps more to be desired than any specific quality of material. It is to be hoped that this coöperation may soon be extended to the foundry and other industries using coke as fuel.[1]

It will assist in following the few descriptive studies of coke that we have to present, to give a brief account of the generally accepted theory of the coking process. The development of this theory is due to several German investigators, notably

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[1] It is of interest to recall that The Franklin Institute is probably the first scientific organization in the world to go on record in the way of encouraging the utilization of coke in iron manufacture. "In 1835," says Fulton, "The Franklin Institute of Pennsylvania offered a premium of a gold medal to the person who shall manufacture in the United States the greatest quantity of iron from the ore during the year, using no other fuel than bituminous coal or coke, the quantity to be not less than 20 tons."

Muck,[2] Hilgenstock,[3] Rau,[4] and Simmersbach,[5] and it has received such abundant confirmation from every practical standpoint that there can be no question of its soundness.

Let Fig. 1 represent a section across a by-product coke oven immediately after the charge of coal is introduced. The layer of coal next to each wall *A* and *B* is very rapidly heated. A complicated process of destructive distillation begins, and at a

FIG. 1.

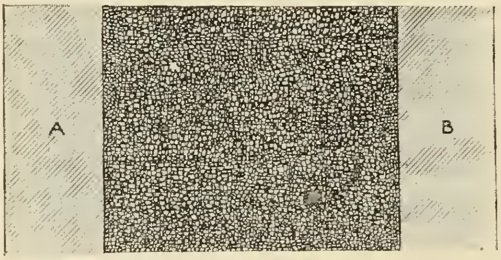

FIG. 2.

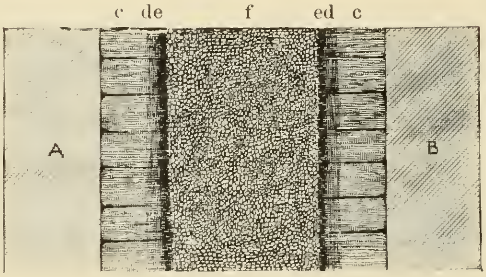

FIG. 3.

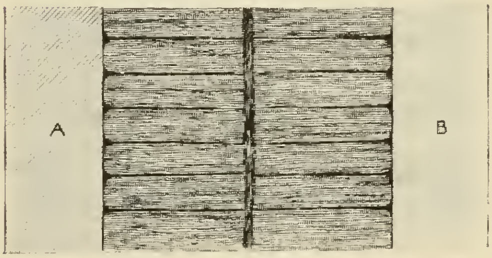

Diagram of the coking process.

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[2] "Chemie der Steinkohle."

[3] *Jour. für Gasbeleuchting,* 45, 1902, p. 617.

[4] *Stahl und Eisen,* 1910, p. 1240.

[5] "Grundlagen der Kokschemie," Berlin, Julius Springer, 1914.

temperature of about 375° to 400° C. the layer becomes soft and pasty. The pasty mass is for a while in a state of violent ebullition, due to the rapid expulsion of its volatile matter, and then rapidly solidifies, the indurated residue retaining the vesicular form and structure of the pasty, foaming stage.

The adjacent layer toward the interior has in the meantime reached the pasty stage, the fusion being assisted by the penetration of some of the soft material forced over from the outer layer. The gases and vapors follow always the line of least resistance and pass through the porous outer layer and up along the wall of the oven instead of forcing their way through the viscous inner portion of the fused layer, and then through the mass of coal. In passing through the highly-heated porous layer, the hydrocarbons undergo a partial secondary decomposition, depositing part of their carbon on the cellular surfaces, just formed, thus building up and strengthening the coke. The coking process is thus to be conceived as involving the formation of a fused zone, and the gradual advance of this zone toward the centre of the oven, the evolved gases and vapors depositing part of their carbon in the vesicular mass left as the zone progresses. The condition of the material in the oven when the coking has fairly well advanced may be represented by Fig. 2. *c* is the portion already coked, *d* is the fused zone merging into an adjacent zone *e*, which, being in a state of incipient fusion, is more viscous. *f* is the uncoked coal.

The actual thickness of the fused zone is probably not over one-half inch. The drop of temperature across this narrow zone is very great, and the interior of the oven remains comparatively cool, even at an advanced stage in the coking process. Simmersbach's experiments[6] on a Koppers oven of 500 mm. (19⅞ inches) mean width, operating on 29 hours' coking time with a final maximum temperature of 1120° C., showed that the temperature in the middle of the oven, 1 metre above the floor, remained about 10° C. for 2.5 hours after charging; then rose to 100° C., and remained at this temperature until 13 hours after charging. At 20 hours the temperature was only 410°.

The rate of advance of the two zones toward the centre of the oven depends principally upon the temperature of the walls

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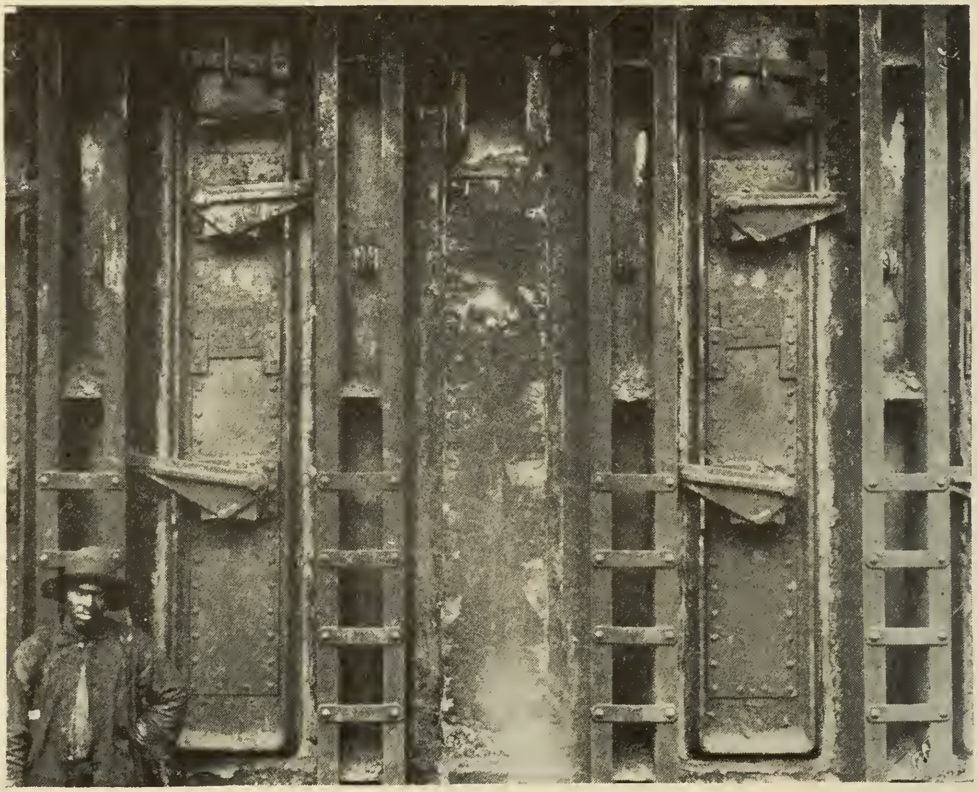
[6] *Stahl und Eisen*, June 14, 1914, p. 954.

(*A*) and (*B*). In present practice, with ovens 18 inches wide and wall temperatures about 1000° C., the average rate is about one-half inch per hour. The initial rate is, however, much more rapid than this, and decreases as the centre of the oven is approached.

As the coking progresses, cracks or joints develop perpendicular to the walls of the oven, thus determining the blocks of coke as they are eventually formed when the oven is discharged.

FIG. 4.

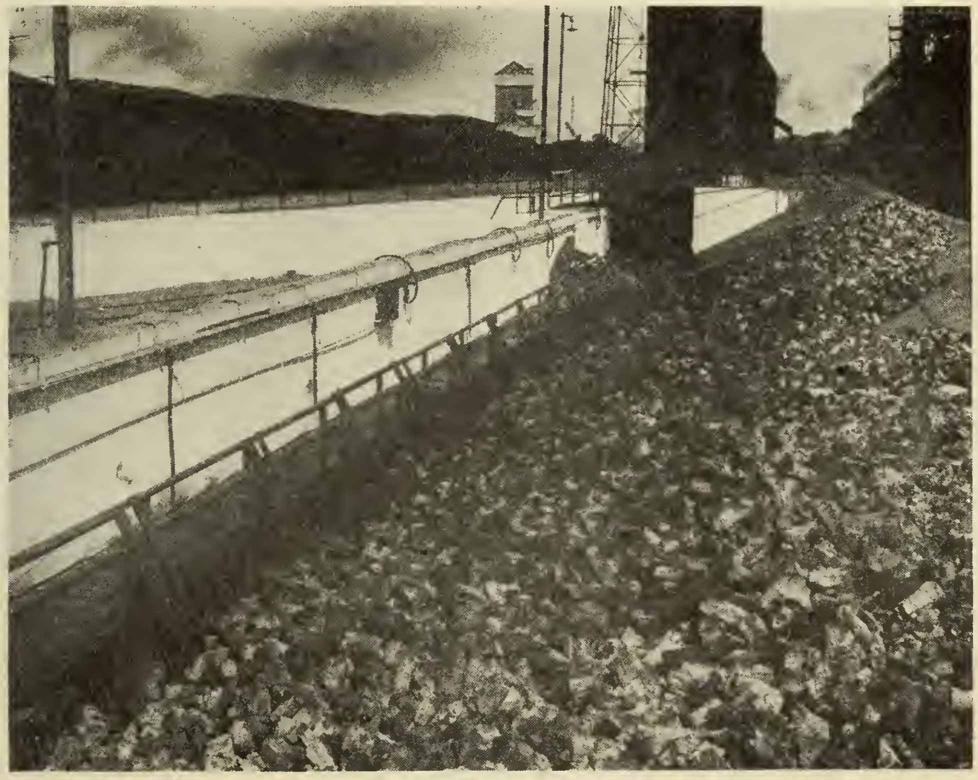


Coke in by-product oven just after removing door.

These cracks form avenues of escape for a large percentage of the gases, hence the amount of deposited carbon is greater in proportion on the surfaces of the blocks than in the interior. Eventually the two zones merge at the centre of the oven (Fig. 3), and, with the practically complete expulsion of the last of the volatile matter, the coking process is finished. There is always a distinct parting in the centre of the oven, so that the length of the blocks is equivalent to about half the width of the oven. Fig. 4 shows a view of the coke as it appears when the door of the oven is removed. Most of the coke immediately adjacent to the walls of the oven is covered with a skin of carbonized pitch. The true form of the blocks may be seen in a few places where this has been broken away.

Fig. 5 shows a lot of standard by-product coke used on one of the lake furnaces as the material appears on the wharf, just after being run out from the quenching car. Fig. 6 shows a closer view of another typical coke. In this figure the individual blocks may be seen more distinctly. A few characteristic blocks are shown in Fig. 7. The three smaller pieces in this figure are cross-sections. The end of the block (Fig. 8) that was originally adjacent to the wall of the oven may always be distinguished by its cauliflower-like appearance and dense layers of deposited carbon. We shall designate it as the wall end and shall call the other extremity the centre end, for want of a better term. The structure of the coke towards the centre end is always more open, and occasionally is somewhat spongy.

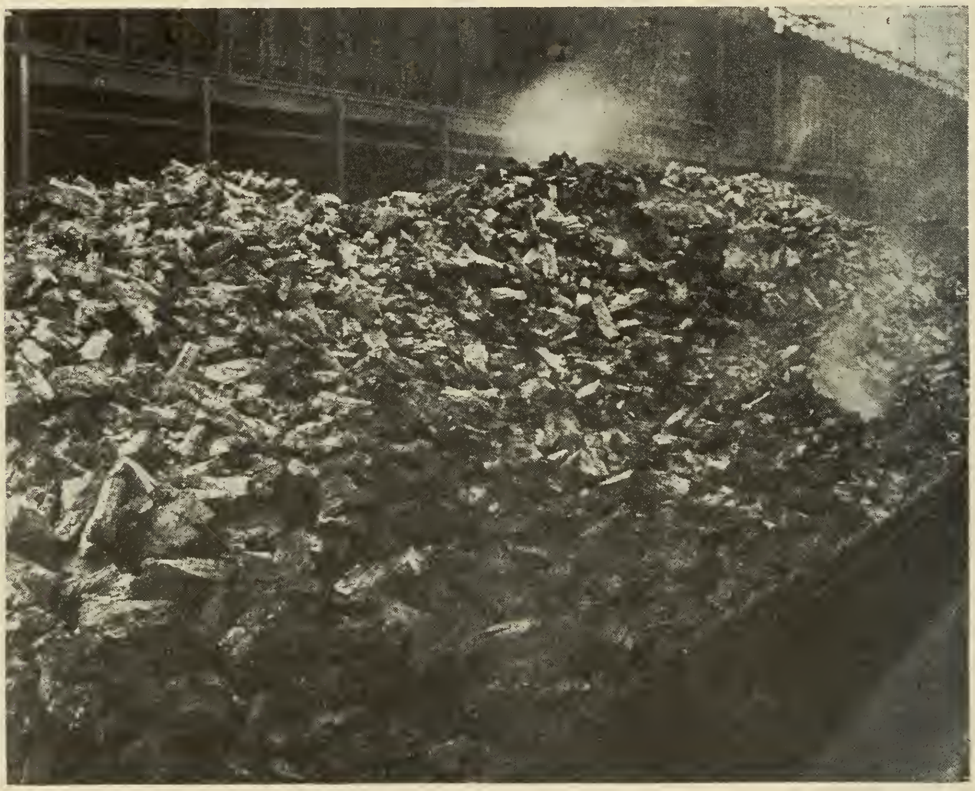
FIG. 5.



Blast-furnace coke, Lake District.

The shape of the coke is quite characteristic, depending upon the coal from which it was produced, and also, to a considerable extent, upon the method of heat treatment. The coke-oven man classes his product as either "blocky" or "fingery," coke of the former character being preferred. Some typically fingery coke is shown in Fig. 9. As a rule, the coke from coals of over 30 per cent. volatile matter is apt to have a fingery tendency—and this becomes highly pronounced if the coal has a high oxygen content. By coking such coals very slowly at temperatures somewhat lower than used in ordinary practice, the fingery tendency may be disguised or in many cases entirely eliminated. By disguising it, we mean that the product will actually appear to form large, massive blocks, but these blocks, if closely examined, will be found actually to be bundles of slender pieces more or less firmly cemented together. However, if the heat treatment be very carefully regulated during the coking process—especially in ovens designed and adapted to this particular type of coals—

FIG. 6.

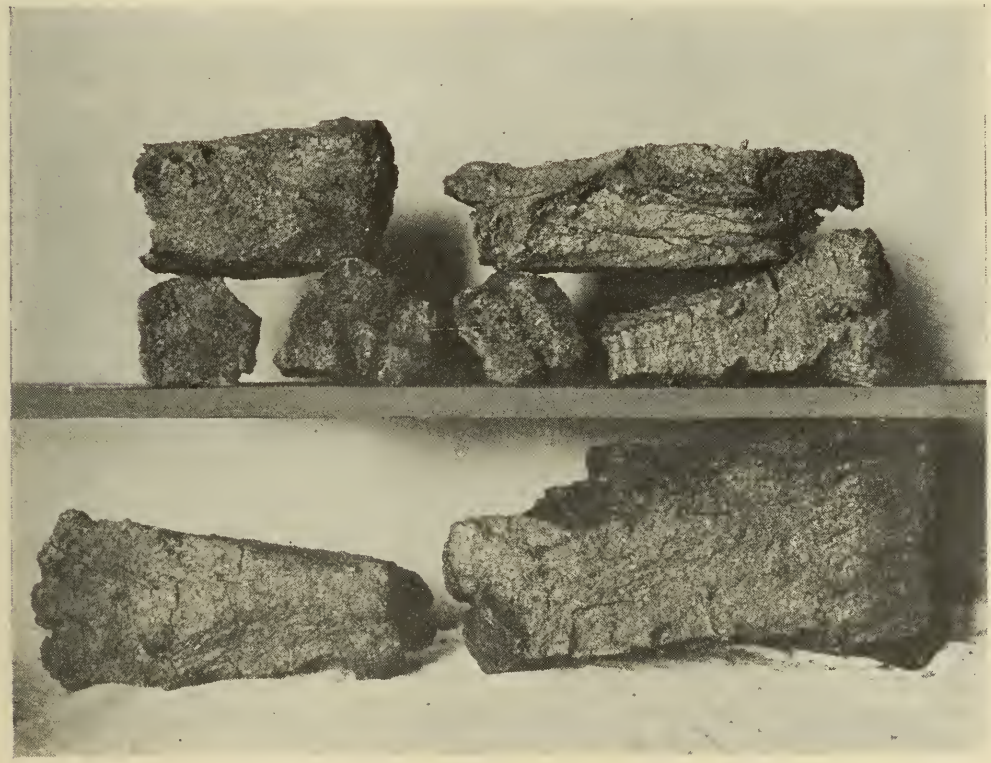


Blast-furnace coke, Atlantic District.

genuine, firm, blocky coke may be made from many coals usually regarded as producing only the fingery variety.

The size of the blocks is affected to a certain extent by almost all the conditions pertaining to the manufacture of coke. The length is, of course, dependent upon the width of the oven, the average being, on account of shrinkage, a little less than half the width of the oven. The blocks from the top of the oven are usually (especially with high volatile coals) shorter than those from the bottom. Overcoking and high temperatures tend to produce small-sized coke.

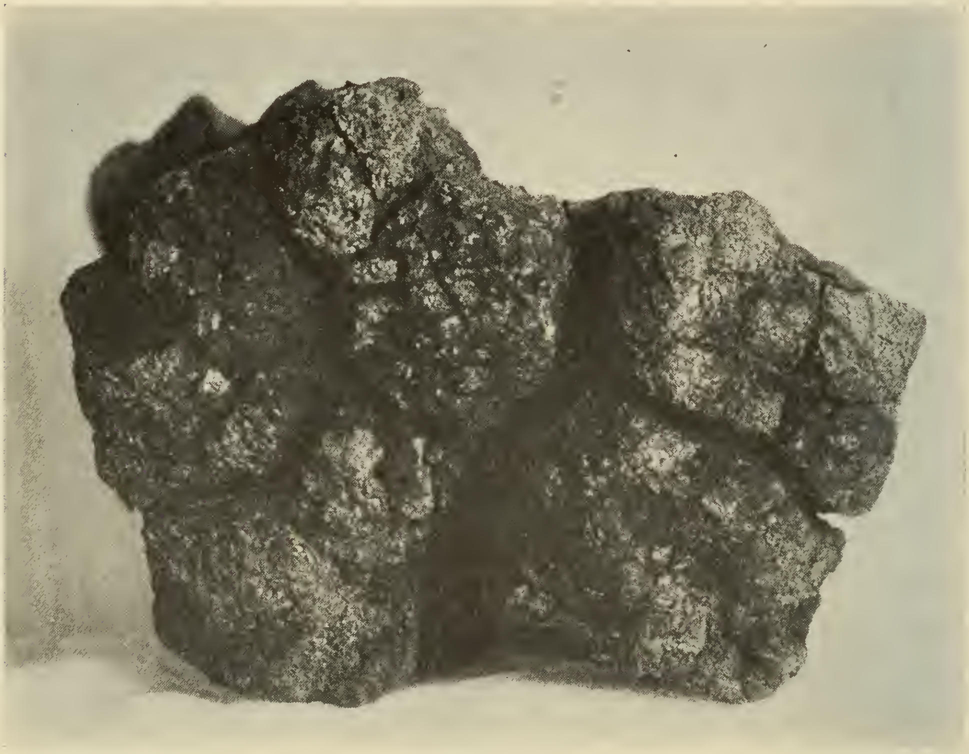
Fig. 7.



Typical by-product coke.

Coming now to an examination of the natural surfaces of the blocks, we may, in the first place, disregard the color as being relatively unimportant. It depends largely upon the method of quenching, and, to some extent, on the quality of the water used, the use of large amounts of water causing a dark color, while with the careful use of a minimum quantity of water a light gray color can always be preserved. The majority of cokes produced from the standard coking coals rich in hydrocarbon production and low in oxygen have close-textured, even surfaces, with possibly a few narrow, transverse zones of slightly larger cell openings interspersed between the two extremities. Many cokes from coals of the Connellsville (Pa.) type show the same silvery, glossy skin that used to be so much prized in beehive coke. This is probably indicative of a very heavy deposit of carbon, especially favored by slow and uniform evolution of a very rich gas.

FIG. 8.



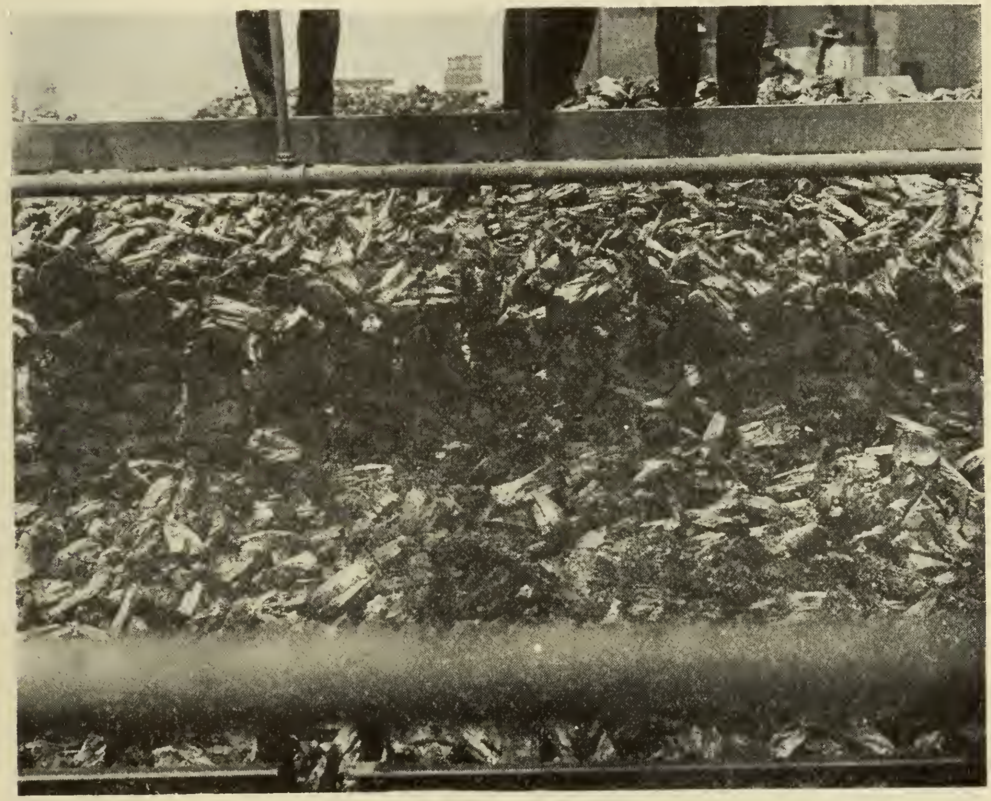
Wall end of a block of coke.

Other cokes, fully equal in value to the above, are characterized by a peculiar shaggy appearance, as if they were covered with blotches of dark moss. This appearance is usually found in cokes produced from mixtures of eastern coking coals with the somewhat more highly oxygenated coals of the central field. Oddly enough, both types of coal usually make smooth coke if carbonized separately.

Certain cokes present transverse pebbly seams—usually not more than two or three. These seams are very narrow and quite coherent, and may be shown to be composed of small globules of quite pure carbon, with no apparent cellular structure. This phenomenon again appears to be characteristic of the more highly oxygenated coals.

The surfaces always show more or less transverse and longitudinal cracks, significantly at right angles—either parallel or perpendicular to the wall of the oven. Naturally these are an element of weakness, and their presence to an excessive degree is one of the surest "first-hand" indications of an inferior grade of coke that we have. The amount of fracturing can be controlled to a surprising extent by proper method of heat treatment.

FIG. 9.

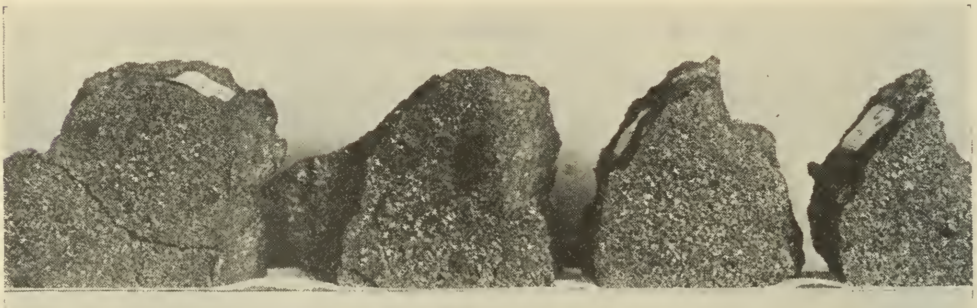


Fingery coke and sponge (Colorado coal).

By breaking a piece of coke and examining the fresh surfaces we find revealed the cellular structure that is characteristic of all cokes and which cannot be seen in its true development simply by inspecting the dense natural surfaces. No definition of coke is complete that does not take this cellular structure into account.

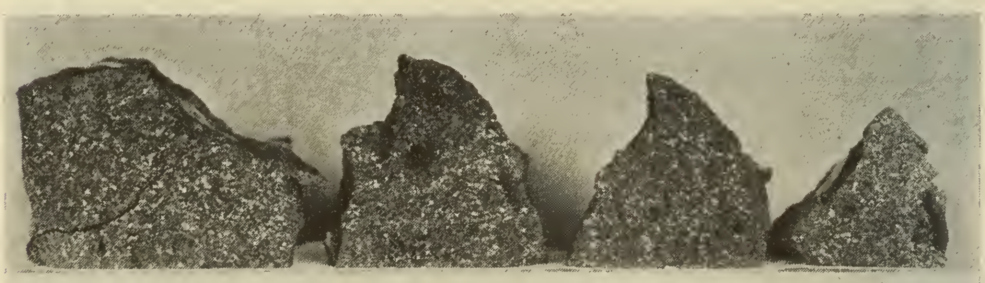
The usual way—and the easiest—to examine the cell structure is to break a piece of coke crosswise and note the appearance of the fresh surfaces. Great care must, however, be taken, in comparing one coke with another by this method, to break the pieces at approximately the same distance from the wall end, since the size of the cells is apt to increase considerably from the wall to the centre. Oddly enough, in many cokes there is a characteristic difference in the two surfaces of a break. No matter where the piece is fractured, the surface on the wall side has almost a granular appearance, with a steel-gray lustre and well-defined cell openings. The opposite surface (*i.e.,* looking toward the centre of the oven) has a characteristic graphitic lustre, with the cell openings flatter and possibly not so sharply defined.

Fig. 10.



CROSS SECTIONS OF COKE AT ABOVE MARKED DISTANCES FROM WALL-SHOWING SURFACES TOWARD CENTER

Fig. 11.



CROSS SECTIONS OF COKE AT ABOVE MARKED DISTANCES FROM WALL-SHOWING SURFACES FACING TOWARD WALL

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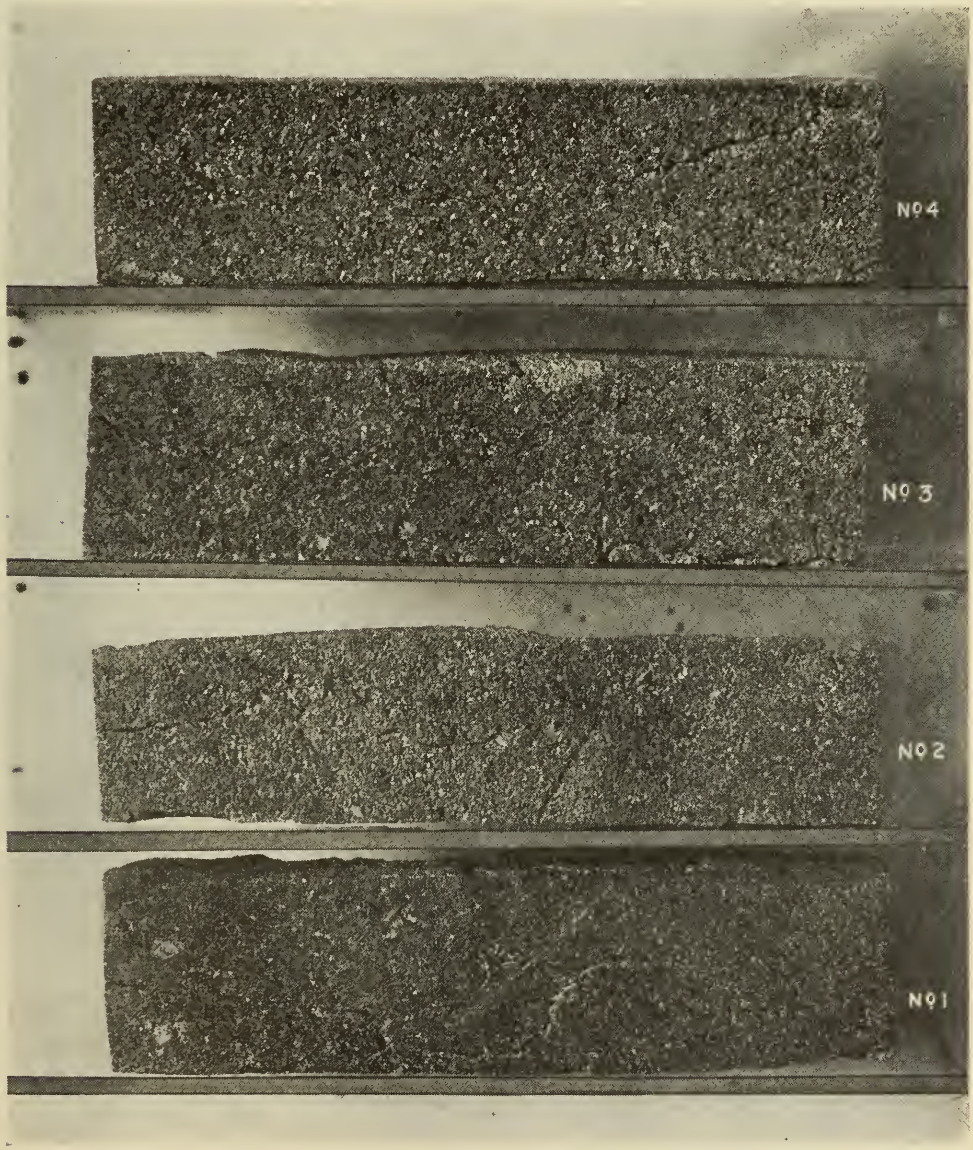
Although this difference is rather hard to depict photographically in a satisfactory manner, we have attempted to do so in Figs. 10 and 11, which will also show the variation of the sizes of cells from wall and to centre. The sections have been made with a 1/16-inch emery wheel at 2, 4, and 6 inches from the wall

FIG. 12.

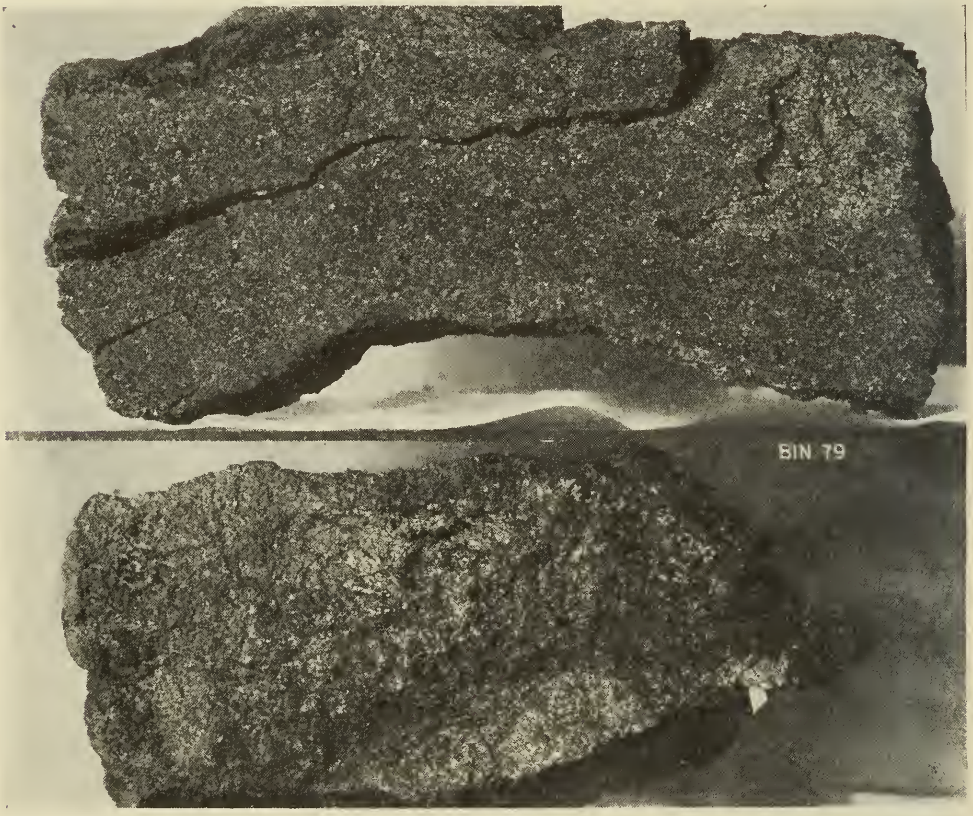


Standards for gauging cell structure.

end of the same block of coke. (This is a standard blast-furnace coke made from a mixture of West Virginia and Pennsylvania coals, and is the same as shown in Fig. 16.) Fig. 10 shows the surfaces facing the centre end of Fig. 11 shows the corresponding surfaces facing the wall; *i.e.,* as one looks at Fig. 9 he is looking toward the wall, and *vice versa* with Fig. 10.

For any accurate comparison of the cell structure of different cokes we prefer to make longitudinal sections with a thin emery wheel—such sections as are shown in Figs. 13 to 21. If this is done, the danger of confusing sections made at different distances from the wall will be largely eliminated. It must be mentioned that *breaking* a piece of coke longitudinally so as to reveal the real cell structure is a decidedly difficult matter. Almost always the break will be found to be made along the plane of a natural longitudinal fracture, and the exposed surfaces will be found to be covered with deposited carbon.

FIG. 13.



Great importance has been attributed to the cell structure of coke by all authorities on the subject, and especially by blast-furnace operators, and yet the subject is very poorly defined and no standards of comparison have been established. We have recently begun the use of a simple system, analogous to the scale

FIG. 14.

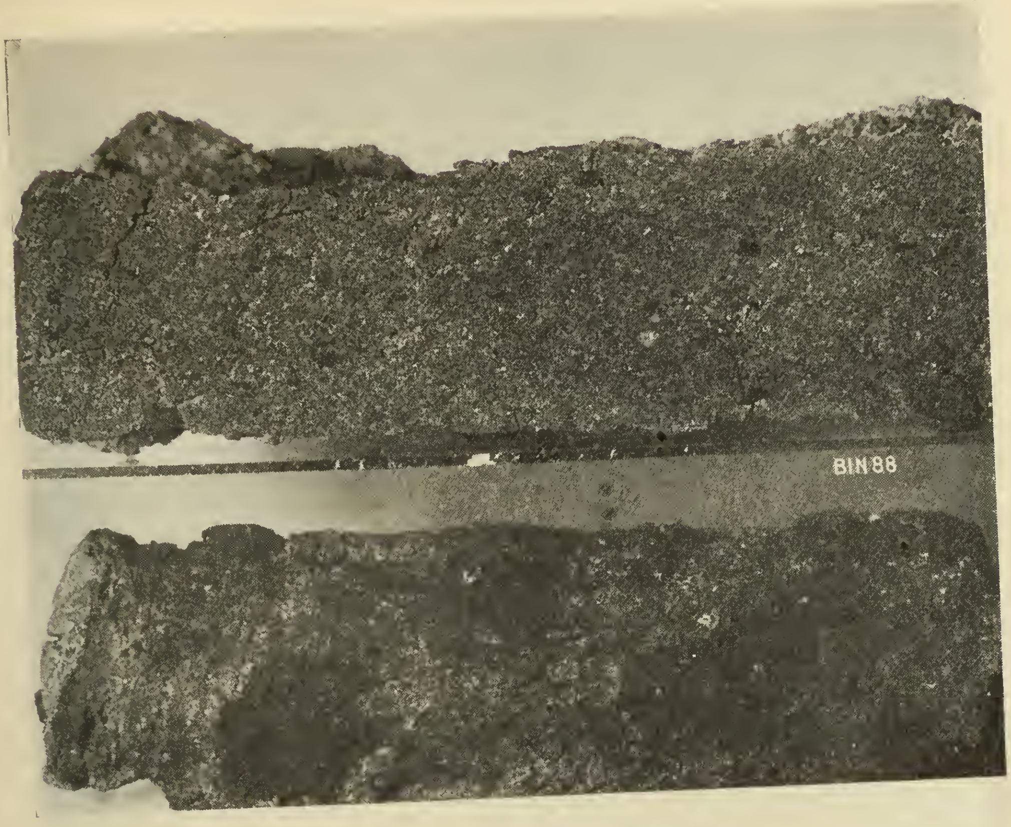
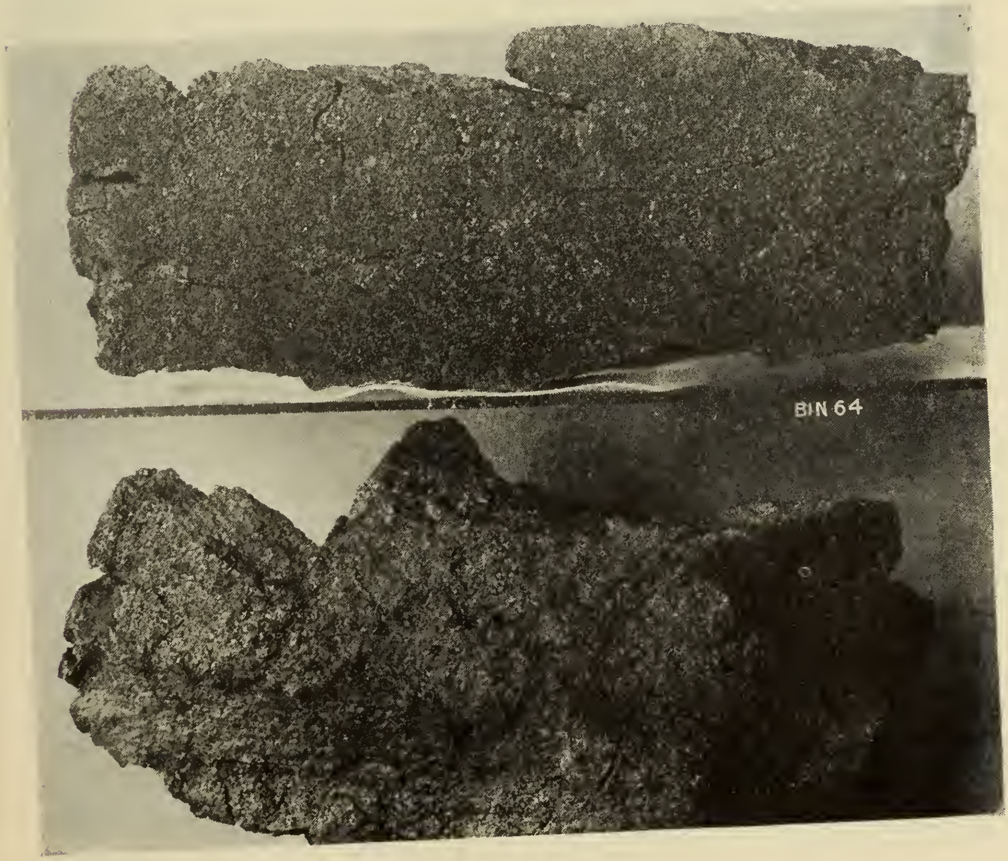
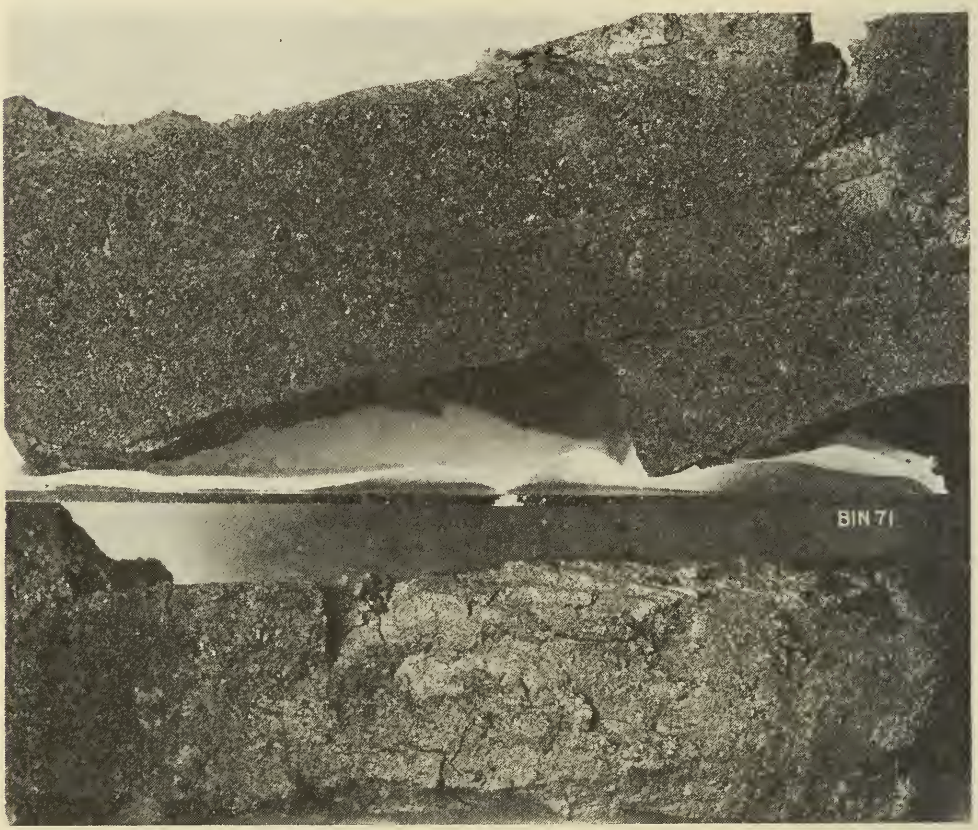


FIG. 15.



of hardness used in the study of minerals, which we hope may come into general favor. At present we employ a set of four standards, shown in Fig. 12. These are all longitudinal sections, cut from blocks of typically different coke. The sections are the same length, and each is cut beginning 1½ inches from the wall end. The sections are numbered 1 to 4 in order of increasing cell size. With such a set of standards it is easy to grade any coke according to its cell structure, and the grading will convey a much more definite idea than the loose terms of "dense," "close," "rather close," "fairly open," "medium," etc., that have hitherto been used. No term in our usual technical vocabularies has been so overworked as the word *"medium,"* as applied to the cell structure of coke.

Fig. 16.



In addition to grading cokes according to the size of the cells, we may also classify them as regular or irregular in cell structure. The standards would all be considered as regular in structure. This does not mean at all that the cells are of the

Fig. 17.

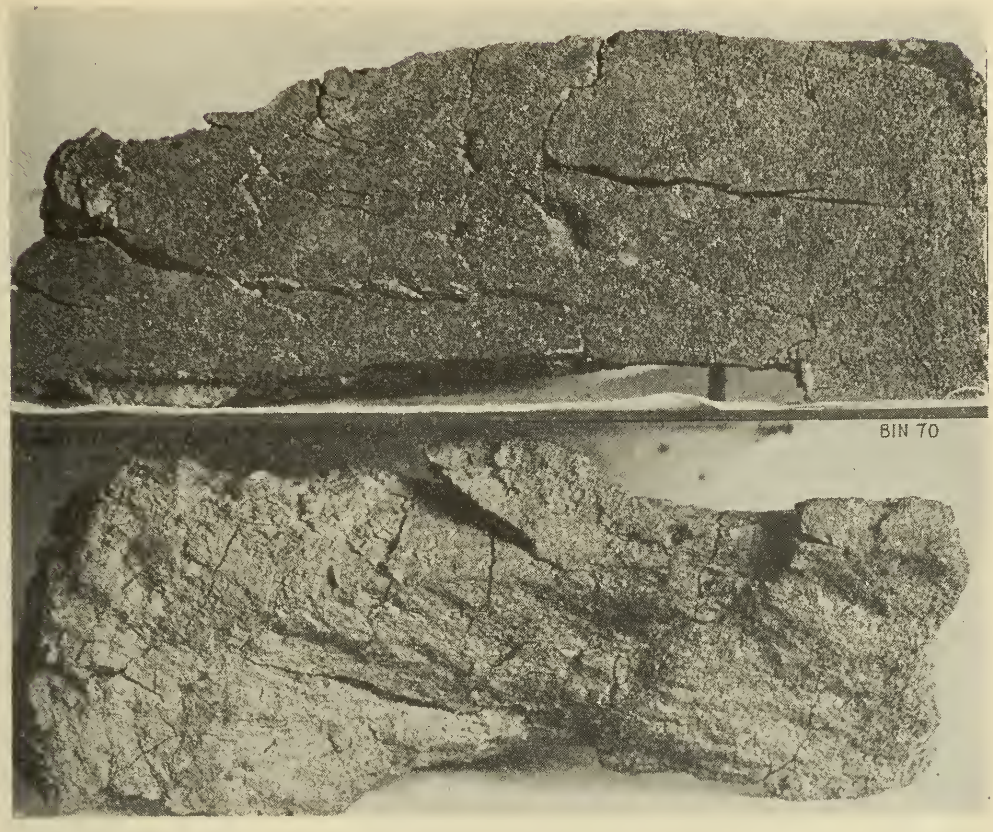
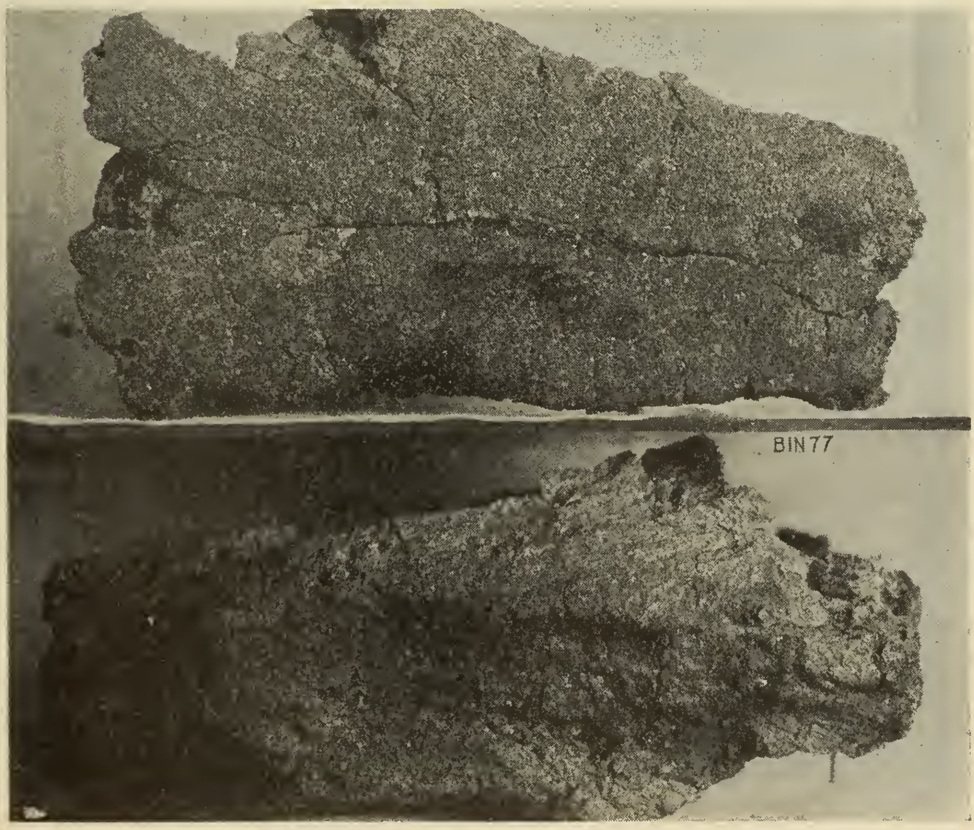


Fig. 18.



same size, but their general arrangement gives an easily perceived impression of regularity. What we mean by irregular structure is illustrated by the sections shown in Figs. 13 and 14. This sort of coke has alternate patches of close and open texture, and is frequently produced by the more highly oxygenated class of coking coals, as well as by mixtures of coals having decidedly different characteristics.

It might possibly be thought now that an interesting table could be prepared grading the cell structure of cokes produced from various typical coals. Such a table would be well-nigh valueless, unless the data were carefully qualified by details regarding preliminary treatment of each coal, dimensions of ovens, temperatures, coking time, and several other factors, each of which plays a part in the development of cell structure. It may be more profitable to show a few sections of different cokes that have given successful results in blast-furnace and foundry practice in various parts of the country. Figs. 13 to 21, inclusive,

FIG. 19.

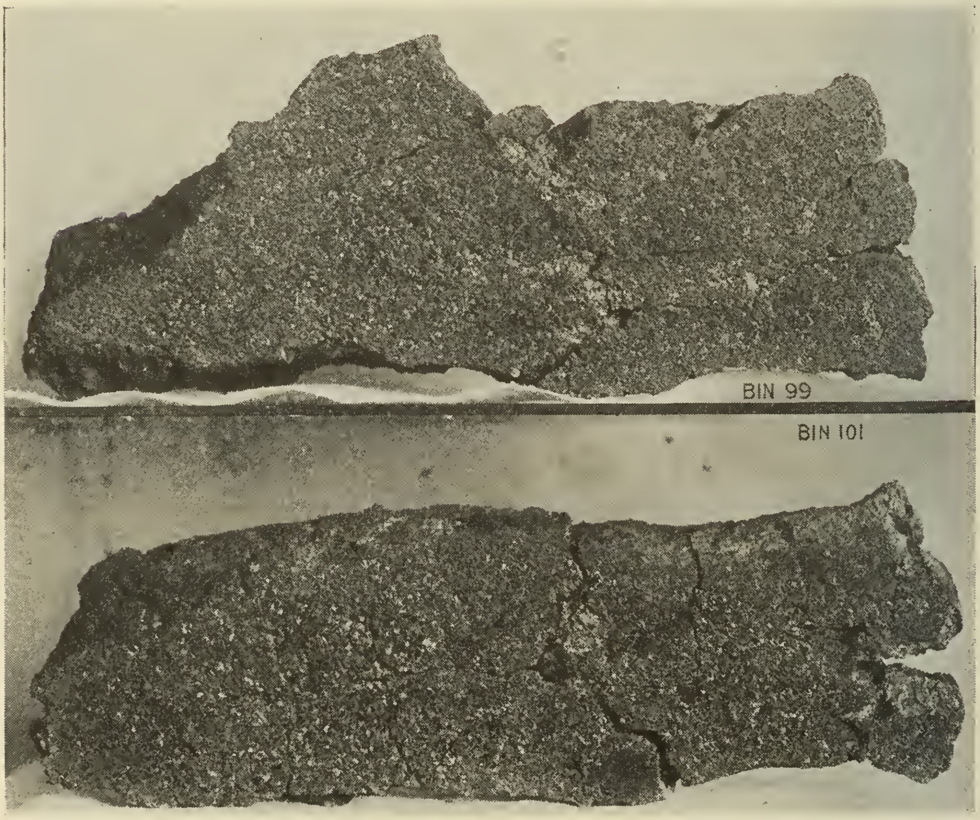


Fig. 20.

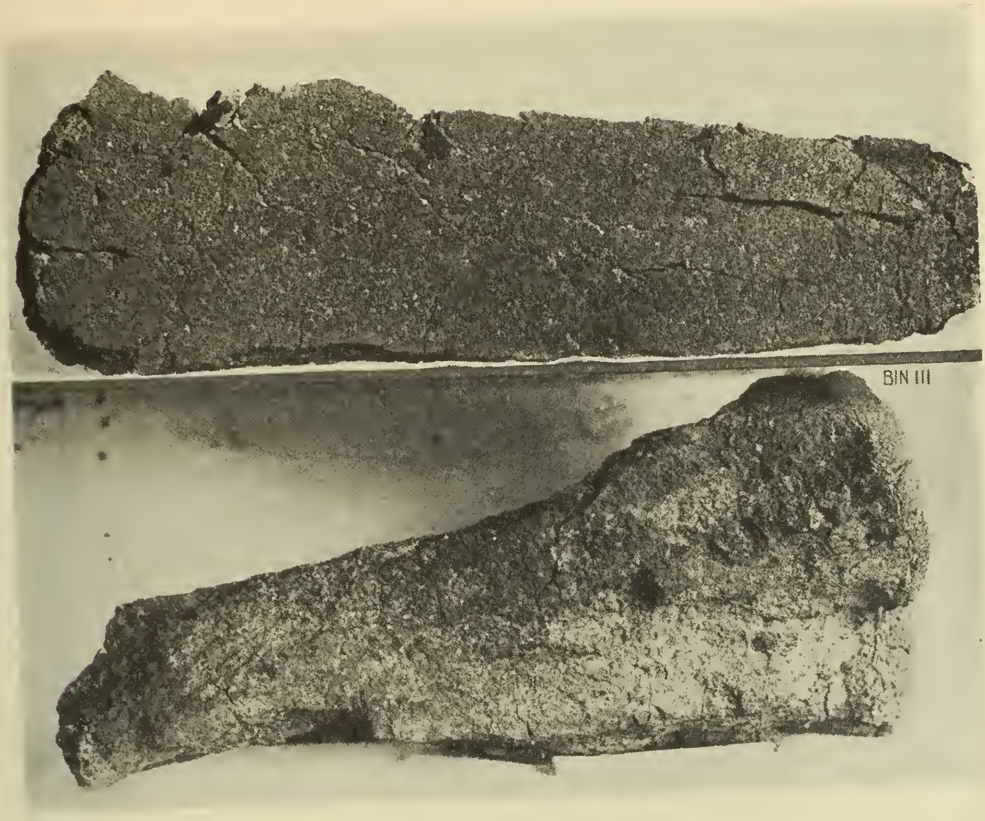
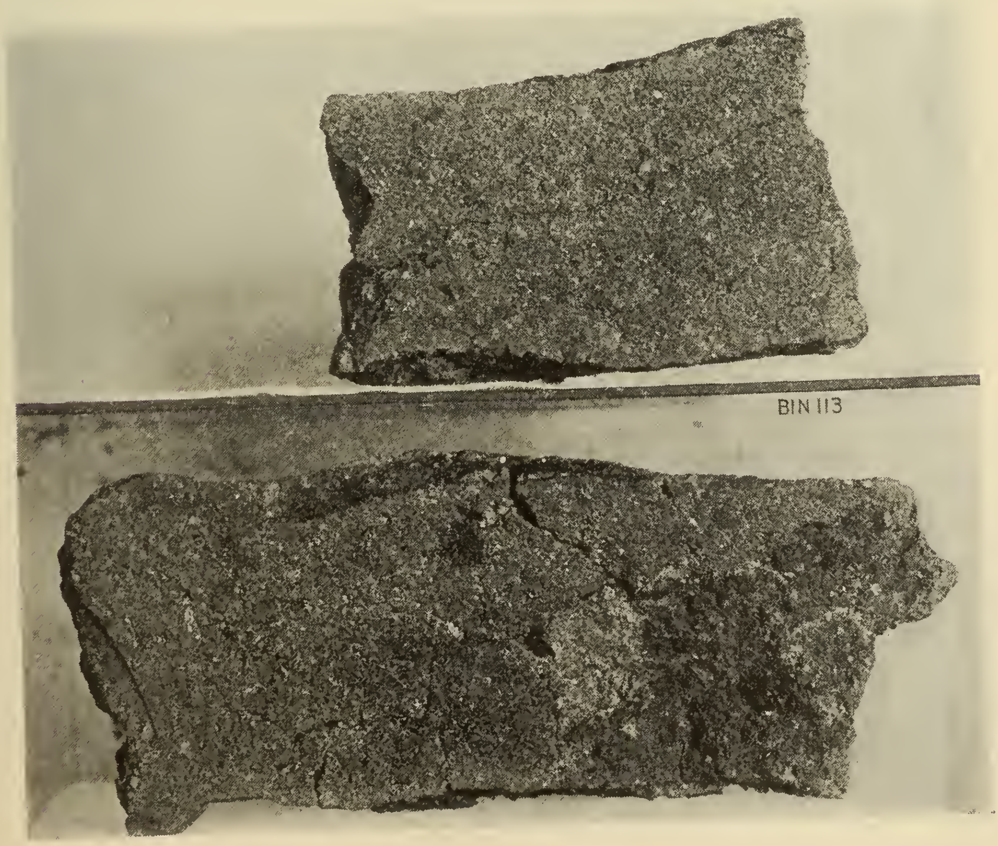


Fig. 21.



illustrate some specimens that have been carefully selected to be as representative as possible.

Sometimes too much reliance is placed in the determination of the specific gravity and porosity of coke. Figures as to porosity or the percentage of cell space in the total volume of coke are almost valueless, unless supplemented by an examination of the actual size of cells and thickness of cell walls. A coke of close texture and thin walls may have the same percentage of cell space as one having large cells and relatively thick walls. As John Fulton[7] the pioneer investigator of coke, said, 34 years ago: "Mere cellular space . . . cannot be used as an element in the practical determination of the value of cokes for blast-furnace use. Furnace gases cannot act on cell spaces; they can only act on exposed surfaces." It is the cell walls and surfaces that are the most important. Cell space and porosity, which is the measure of it, are merely incidental.

The following table of specific gravities and porosities of the coke specimens illustrated in this paper will show that there is really no relation between cell structure and porosity:

TABLE III.

Cell grading	Figure	Apparent specific gravity	True specific gravity	Porosity
1 (Standard)	12	1.097	1.917	42.8
1	14	0.924	2.006	53.7
1.5	13	0.974	1.891	48.5
2 (Standard)	12	1.007	2.028	50.4
2	17	1.138	1.948	41.6
2	18	0.997	1.979	49.6
2.5	15	0.857	1.979	56.7
3 (Standard)	12	1.071	1.831	41.6
3	20	1.053	1.917	45.1
3	21	0.854	1.862	54.1
4 (Standard)	12	0.943	1.988	52.6
4	16	0.943	1.988	52.6
4	19	0.917	1.921	52.3

For ordinary purposes in grading cell structure magnification is unnecessary. Photographic enlargement gives some interesting information as to the character of the cell walls. Figs. 22, 23, 24, and 25 show portions of standards Nos. 1, 2, 3, and 4, respectively, each enlarged 10 times. There is considerable apparent irregularity of cell diameter, due to the fact that the cells are cut in different planes, but the comparison of the four types of coke is fairly good.

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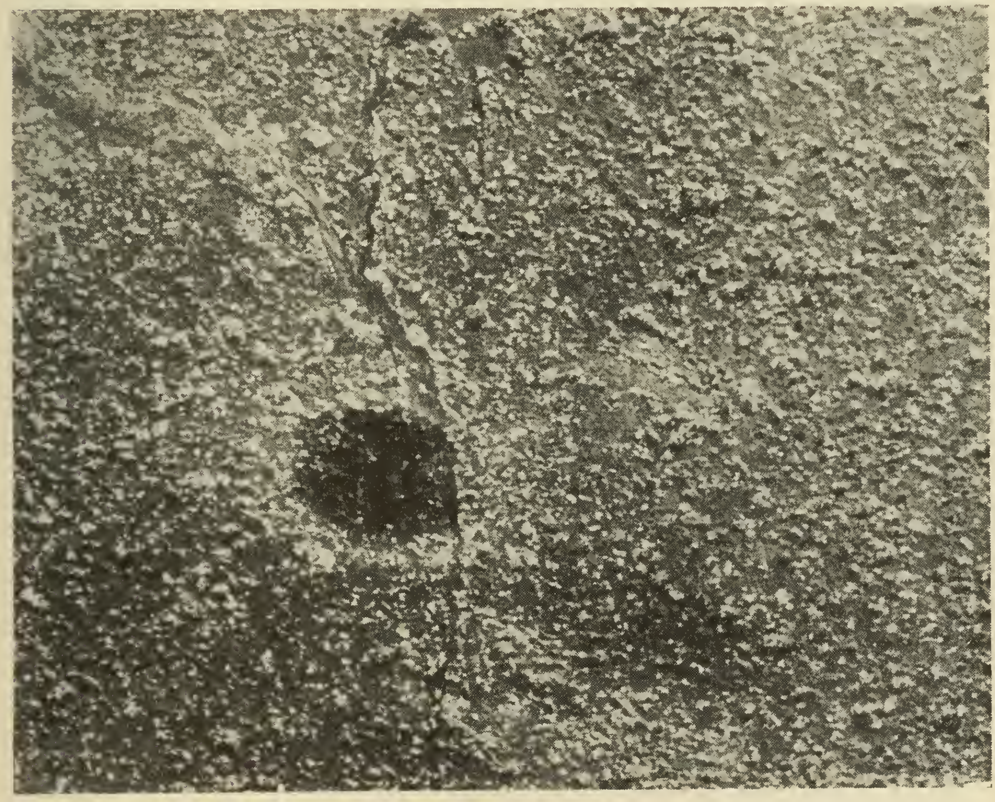
[7] *Bull. Am. Inst. Min. Eng.*, October, 1883.

In passing from this subject of the examination of coke sections we should take occasion to point out the interesting field that is here open for the application of petrographic methods to an exhaustive investigation of the material. The actual chemical and physical state of the carbon produced from various coals under various conditions is an important matter from a practical standpoint. Differences in the true specific gravity of coke are frequently found that cannot be explained by variation in the content of inorganic matter. The actual condition of this inorganic matter after carbonization, the amount of reduction of the various oxides, the possible effect of the finely-disseminated mineral matter in strengthening or weakening the cell walls are

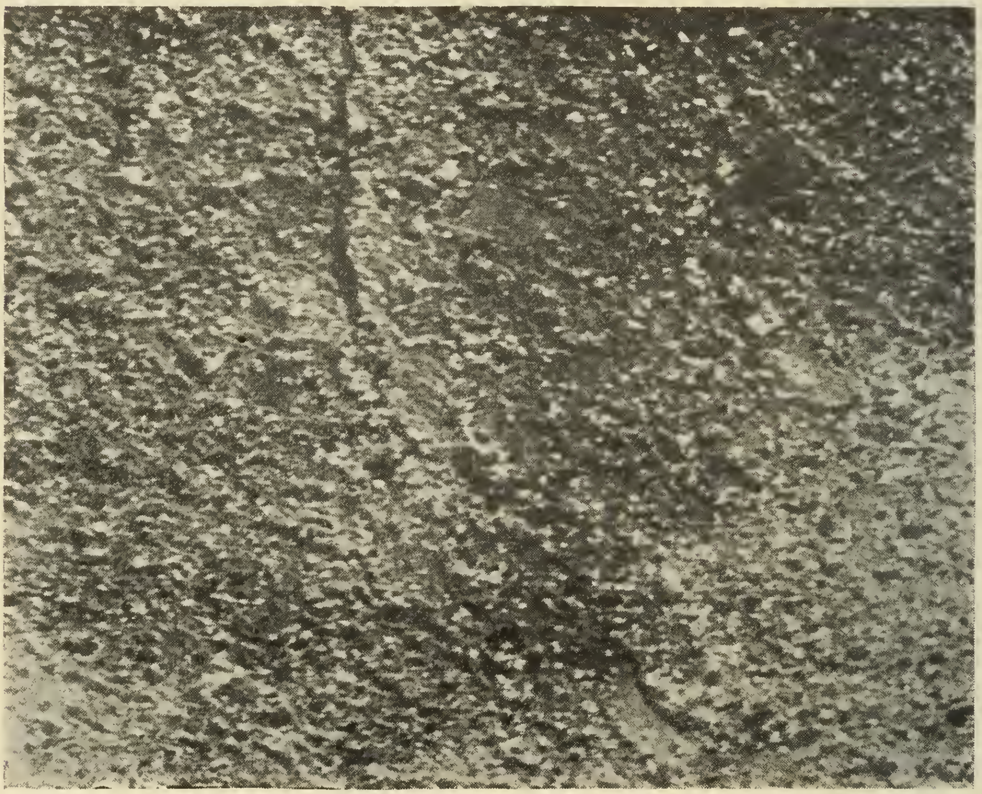
Fig. 22.



Standard No. 1, enlarged 10 diameters.

all very important. Inorganic matter does not necessarily constitute an element of weakness. Large particles, especially if segregated, are injurious, but finely-divided mineral matter may actually strengthen the cell walls. High-ash cokes are frequently stronger than low-ash cokes from the same kind of coal. Some experiments in washing and coking coals of moderate ash content have shown that where the original coal gave a strong coke, the washed coal gave a weaker coke, the difference being undoubtedly due, to some extent, to the removal of some of the mineral matter, although the high moisture content of the washed coal might have had some effect. Simmersbach gives some evidence to show that iron present in combination with carbon and silicon, and silicon present as a silicon carbide, may be the cause of the remarkable hardness of some coke.

Fig. 23.

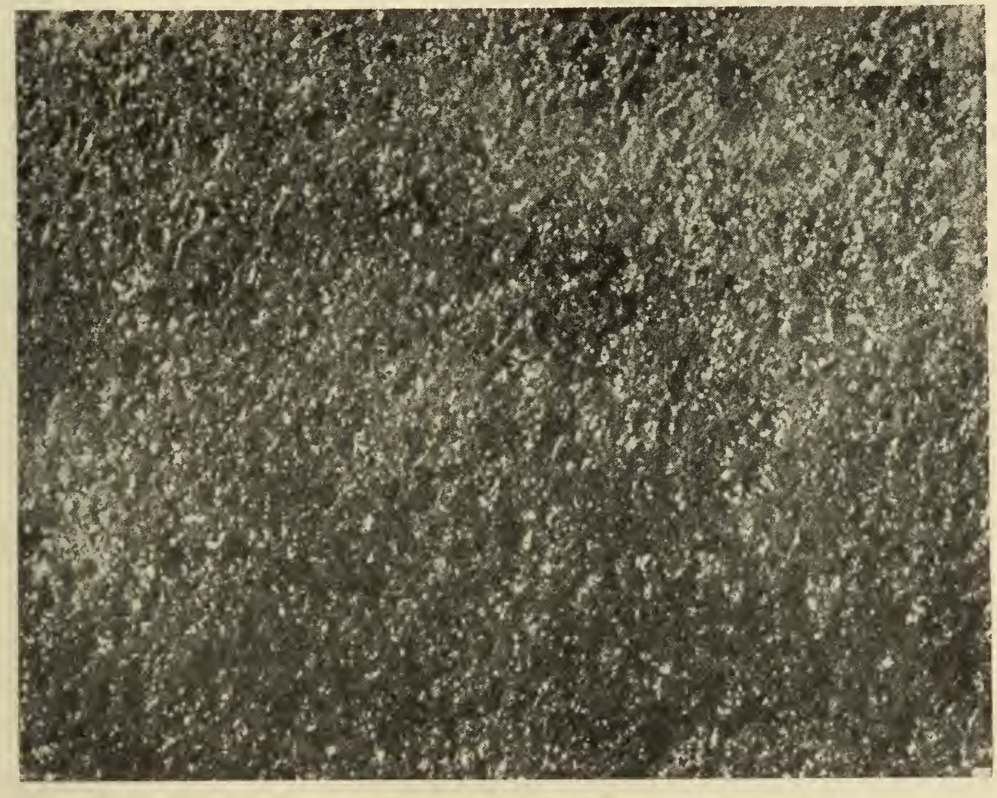


Standard No. 2, enlarged 10 diameters.

Studies of this character will, however, be largely of academic interest unless correlated with studies of the behavior of different types of coke in the blast furnace and in other types of apparatus in which the material is used. Let us choose the blast furnace for consideration here on account of its tremendous industrial importance.

There is at present some disagreement among blast-furnace men as to the exact function of the coke in the most efficient and economical reduction of iron ore. The majority probably still accept Grüner's theory of ideal working, viz. (as stated by Richards[8]), "All the carbon burnt in the furnace should first be oxidized at the tuyères to CO, and all reduction of oxides above the tuyères should be caused by CO, which thus becomes CO_2." It is well known that the reduction of iron oxide by carbon monoxide is the most efficient from the standpoint of heat economy. Richards, however, has pointed out that the direct reduction of iron oxide by carbon is three times as efficient from

FIG. 24.



Standard No. 3, enlarged 10 diameters.

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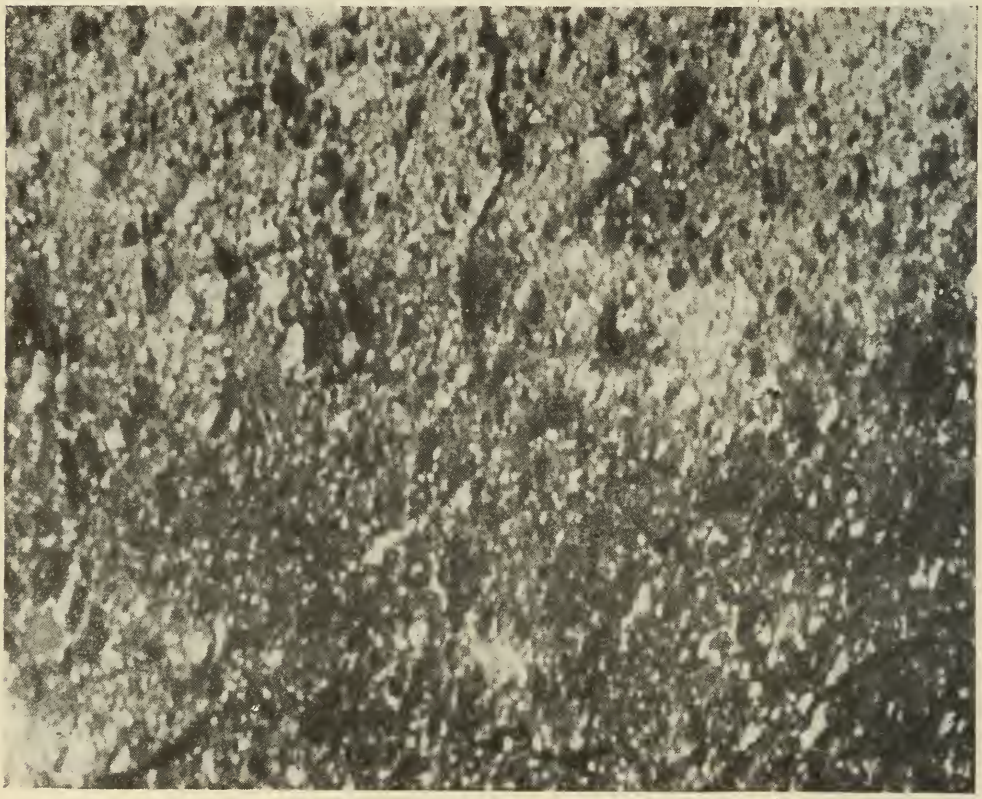
[8] "Metallurgical and Chemical Calculations," p. 248.

the standpoint of carbon required as the indirect reduction, and says:

"The ordinary furnace produces at the tuyères, in order to get heat enough to melt down the charges, more CO gas than is needed to abstract all the oxygen from the charges; under these conditions it is uneconomical to oxidize any carbon at all above the tuyères. The exceptional furnace, because of pure ores, small amount of slag, pure fuel, high temperature of blast, or dry blast, gives heat enough at the tuyères to melt down the charges without producing enough CO gas to reduce all the charges; under these conditions, more or less reduction is effected by solid carbon and with the greatest economy in quantity of carbon required in the furnace."

FIG. 25.



Standard No. 4, enlarged 10 diameters.

About a year ago Mr. H. P. Howland prepared an interesting paper,[9] entitled "Calculations with Reference to the Use of Carbon in Modern American Blast Furnaces," calling attention to the fact that many furnaces are actually operating with higher economy of coke than would be calculated from Grüner's theory; in fact, his calculations on the performance of 26 furnaces seem to show that what Richards regarded as the exceptional furnace is the rule rather than the exception in modern practice.

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[9] *Bull. Am. Inst. Min. Eng.*, March, 1916, p. 627.

Howland's tabulation of data on these 26 furnaces is so interesting and pertinent to the subject that we are reproducing a portion of it herewith:

Furnace No.	Pound coke per ton iron.	Tons iron per day.	Carbon in coke per cent.	Kind of method of manufacture.	Coke operation.	Total charged.	Gasified in furnace.	Gasified at tuyeres.	Per cent. total carbon.	Per cent. gasified carbon.
1	2,615	301	86.3	BH	Stonega	2,254	2110	1868	82.8	88.6
2	2,551	272	84.4	BP	Solvay	2,153	2049	1751	81.4	85.6
3	2,472	482	86.1	BH	Conn.	2,128	1996	1728	81.2	86.6
4	2,247	450	87.1	BH	Conn.	1,957	1846	1605	82.0	87.0
5	2,198	499	86.9	BH	Conn.	1,908	1810	1494	78.7	82.6
6	2,123	541	88.3	BH	Conn.	1,875	1764	1498	79.8	84.9
7	2,115	360	84.3	BP	Solvay	1,782	1683	1427	80.1	84.8
8	1,996	490	86.3	BP	Koppers	1,722	1611	1298	75.4	80.6
9	1,936	376	85.7	BP	Solvay	1,659	1557	1305	78.8	83.7
10	1,905	393	88.7	BP	Solvay	1,690	1575	1252	74.1	79.5
11	1,901	517	85.5	BP	Koppers	1,625	1524	1280	78.8	84.1
12	1,863	504	86.6	BP	Koppers	1,614	1513	1230	76.2	81.3
13	1,780	426	84.9	BP	Koppers	1,511	1414	1124	74.4	79.5
14	1,742	503	84.6	BP	Koppers	1,474	1382	1133	76.9	82.0
15	1,716	542	87.1	BH	Benham	1,494	1396	1194	80.0	87.0
16	1,715	585	84.6	BP	Koppers	1,451	1357	1114	76.7	82.2
17	1,702	543	87.5	BP	Koppers	1,490	1388	1130	75.9	81.5
18	1,699	572	87.0	BP	Koppers	1,479	1387	1155	78.2	83.4
19	1,673	580	88.6	BH	Benham	1,482	1384	1182	79.9	85.0
20	1,658	590	88.3	BH	Benham	1,464	1366	1182	80.8	86.5
21	1,636	442	89.5	BP	Koppers	1,463	1369	1124	76.8	82.1
22	1,635	593	88.5	BH	Benham	1,447	1349	1124	77.7	83.4
23	1,624	592	87.3	BH	Benham	1,417	1317	1118	79.0	85.0
24	1,623	457	89.6	BP	Koppers	1,454	1360	1090	75.0	80.2
25	1,589	608	88.3	BH	Benham	1,403	1307	1100	78.5	84.2
26	1,584	466	89.2	BP	Koppers	1,413	1324	1057	74.8	79.9

NOTES.—BH = Beehive. BP = By-product. Conn. = Connellsville.

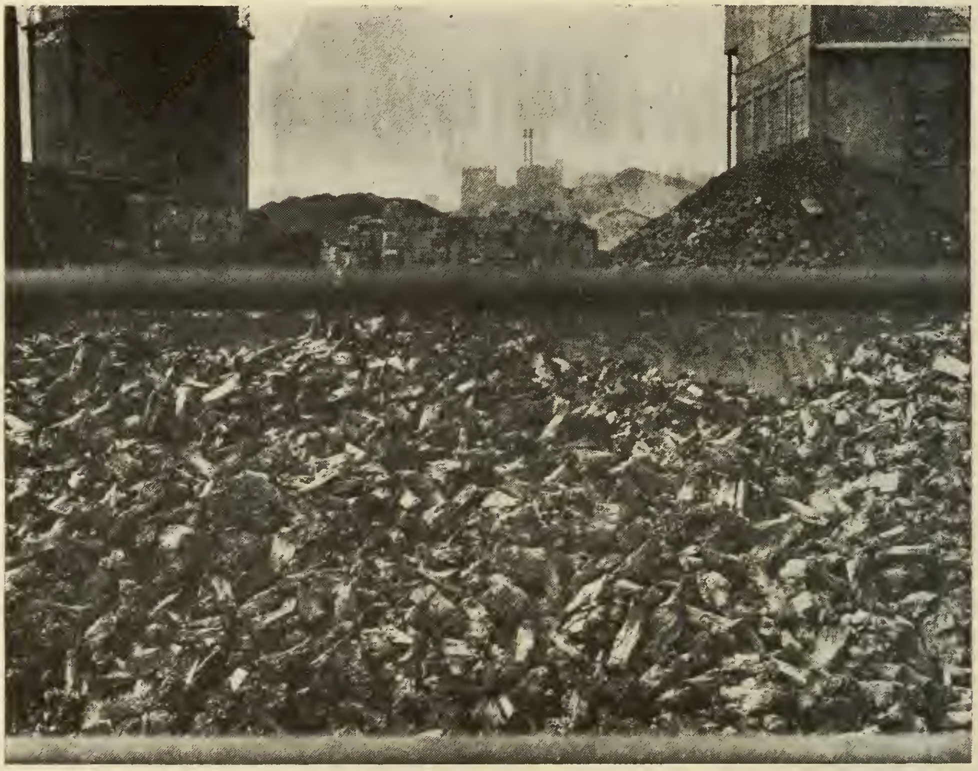
Note incidentally the performance of the once-despised by-product coke in modern practice. Of the 19 furnaces using less than a ton of coke per ton of pig iron, 13 are burning by-product coke and 6 beehive coke.

Howland calculates that all the furnaces burning less than 1350 pounds of carbon at the tuyères are not making enough CO to reduce all the Fe_2O_3 and hence some of the latter must be reduced directly by carbon. He concludes:

"It seems clear, therefore, that in low-coke furnaces one of the most important, if not the most important function of the carbon burned at the tuyères is to produce heat to enable the carrying on of the direct reduction, rather than to produce CO for indirect reduction.

"On this basis, it becomes very essential that our carbon shall burn instantaneously to CO in order that the resulting heat may be localized where needed. This should not be a question of seconds, but of a fraction of a second. If our carbon is of such a nature that this burning to CO is a comparatively long process, more of it will be required than of the quick-burning carbon in order to obtain the same concentration of heat at the desired point.

FIG. 26.



Coke from straight high volatile coal, showing sponge.

"We would, therefore, say that the most desirable thing about a coke is that quality in the carbon which will allow of its being instantaneously burned to CO and thus result in the maximum concentration of heat where needed."

W. H. Blauvelt, in a discussion of Howland's paper,[10] says:

"In studying the combustion of coke in the furnace, it is clear that the production of the maximum quantity of heat is not of the first importance in blast furnace operation, or in the utilization of the fuel charged into the furnace. To my mind, the production of a high thermal head at the tuyères is of the first importance, and the best coke is that which reaches the tuyères in proper condition to produce the highest temperature at the tuyères, and in just sufficient quantity to do the amount of work required there under the conditions produced by this maximum temperature. The combustion of a much larger amount of fuel at the tuyères, under conditions that will fall short of producing the highest possible temperature, cannot produce as good results, either in fuel economy or output. . . . Nothing is more fatal to obtaining the highest temperature than an excess of combustion. In the blast furnace an excess of air dilutes and cools the products of combustion, reducing the maximum thermal head at the tuyères, and the larger volume carries the high temperature zone too high in the furnace. . . . It will probably be generally admitted that furnace coke should be of nearly uni-

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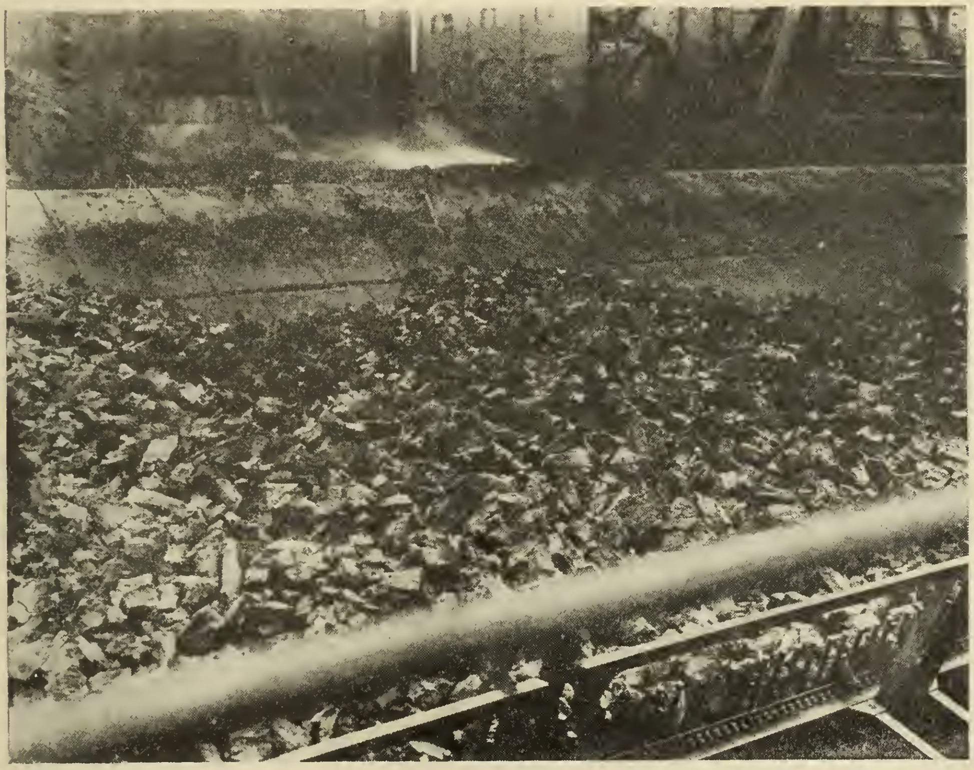
[10] *Bull. Am. Inst. Min. Eng.*, October, 1916.

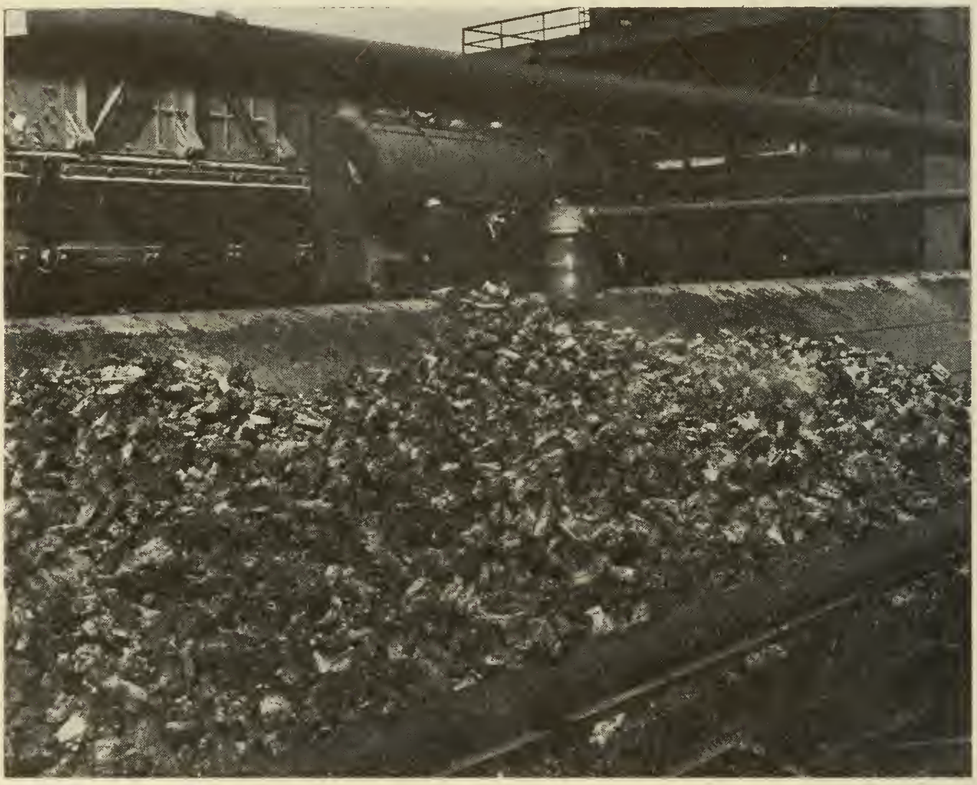
FIG. 27.



Coke from same coal as Fig. 26, with 20 per cent. Pocahontas.

form size, and many furnace managers are eliminating all coke below ¾ inch and above 4 or 4½ inches; also, that the best coke is that which is sufficiently strong to resist undue abrasion and crumbling by attrition with the stock, and of an open porous structure that will permit the most rapid combustion when it reaches the tuyères. Many large users agree that the coke should never be overcoked beyond the point of producing a sufficiently strong structure, as overcoking quickly reduces the combustibility.

FIG. 28.

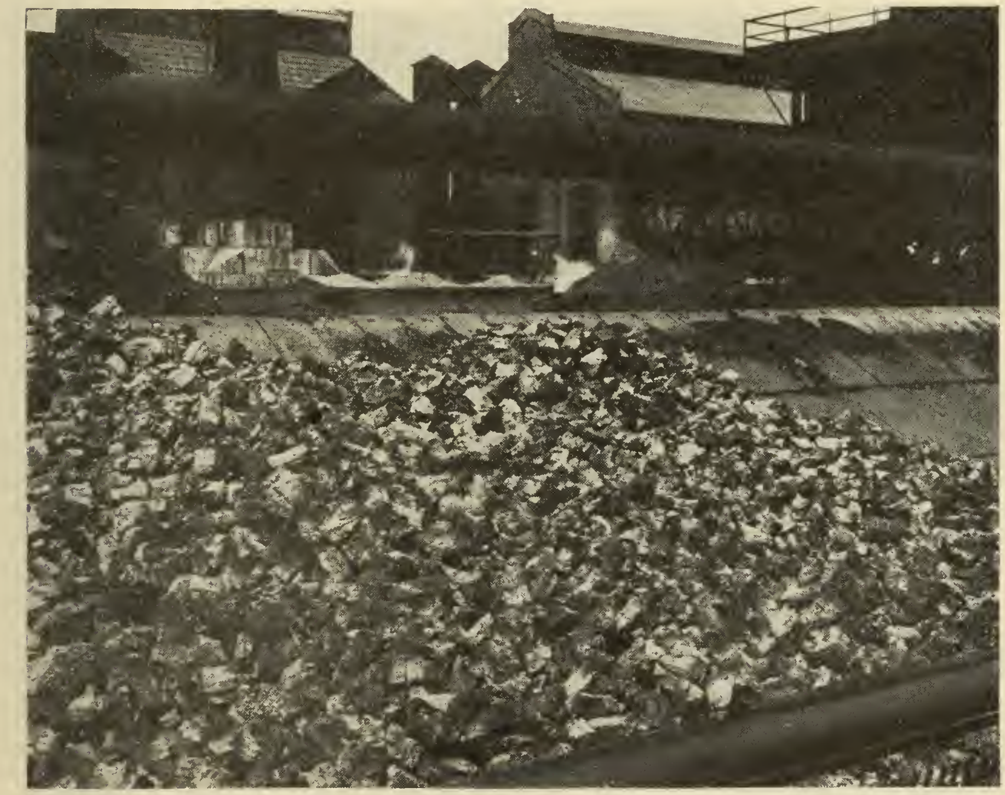


90 per cent. high volatile coal + 10 per cent. Pocahontas.

"If Grüner's ideal gives the best furnace operation, we should want a coke that is resistant to the oxygen in the ore, but easily combustible at the tuyères, which is a contradiction of qualities. If my argument is correct, that the furnace man wants the greatest thermal head at the tuyères rather than the production of the greatest quantity of heat in the furnace as a whole, then he is willing to sacrifice some coke by solution in the oxidizing gases in the upper part of the furnace, provided he can obtain a sufficient quantity of coke at the tuyères, of a quality that will permit rapid combustion with the minimum amount of air. thereby giving him the maximum thermal head."

The desirability of the condition which Blauvelt aptly terms " a high thermal head " in the zone of the tuyères will be readily granted even by those who adhere to Grüner's theory. This condition should be attained even at a sacrifice of some carbon by solution loss ($CO_2 + C = 2CO$), and we are of the opinion that the importance of this solution loss is frequently overestimated.

FIG. 29.



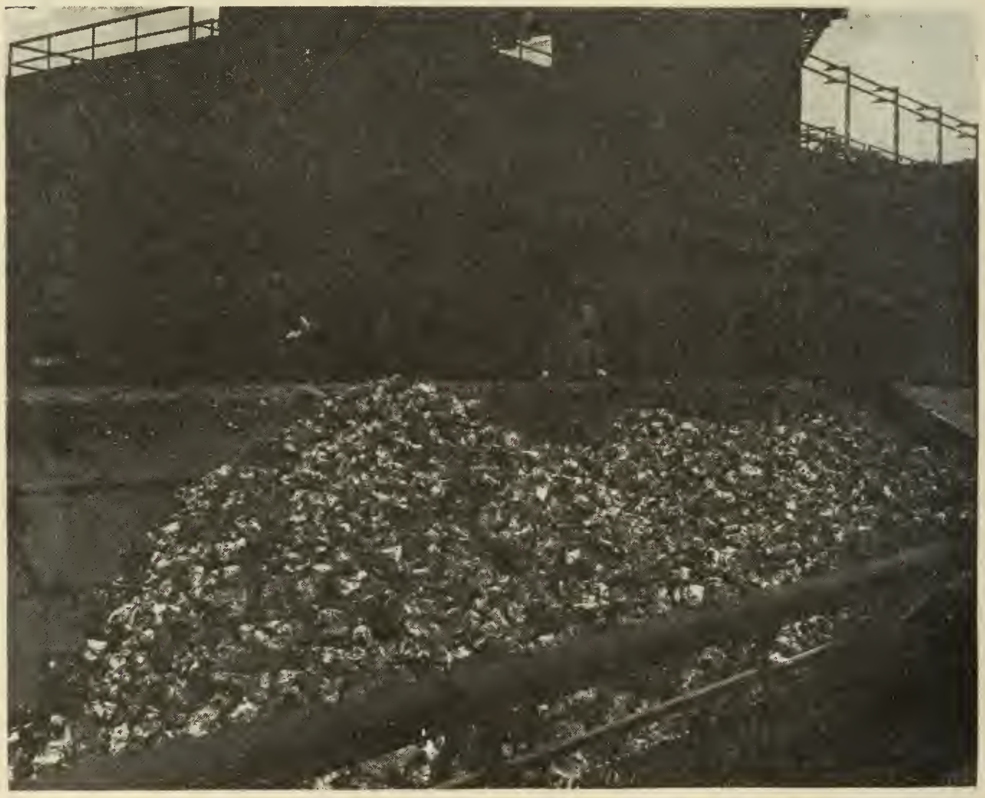
70 per cent. high volatile + 30 per cent. Pocahontas.

Most laboratory experiments made to determine the loss undergone by different cokes have been of little value, because they have been mostly made with pulverized samples, so that their original physical condition has been greatly altered.

We have lately tested the resistance of a number of cokes to the action of CO_2 at temperatures of 800° and 900° C., and find the loss of coke pulverized to 40 mesh to be very much greater than the same coke prepared in small test pieces, 3/8 inch by 3/8 inch by 1 1/2 inches, so as to retain the original structure.

As furnace conditions are better understood the possibility of the use of coke of a wider instead of a more restricted range of quality will become better recognized, with the express limitation that the supply for each furnace must always be absolutely uniform in quality. This requirement of uniformity cannot be too strongly emphasized, and it is almost equally necessary for the proper operation of the coke plant as the blast furnace; but this does not mean that there is one standard grade of coke to which all plants should conform so far as possible. As a matter of fact, the range of cokes that successfully qualify in practical operation is continually being extended, through necessity of one sort or another, with little general realization of the fact. In Figs. 13 to 22 we have already shown the cell structure of some cokes that are giving good results in different American blast furnaces, and the difference is fairly remarkable.

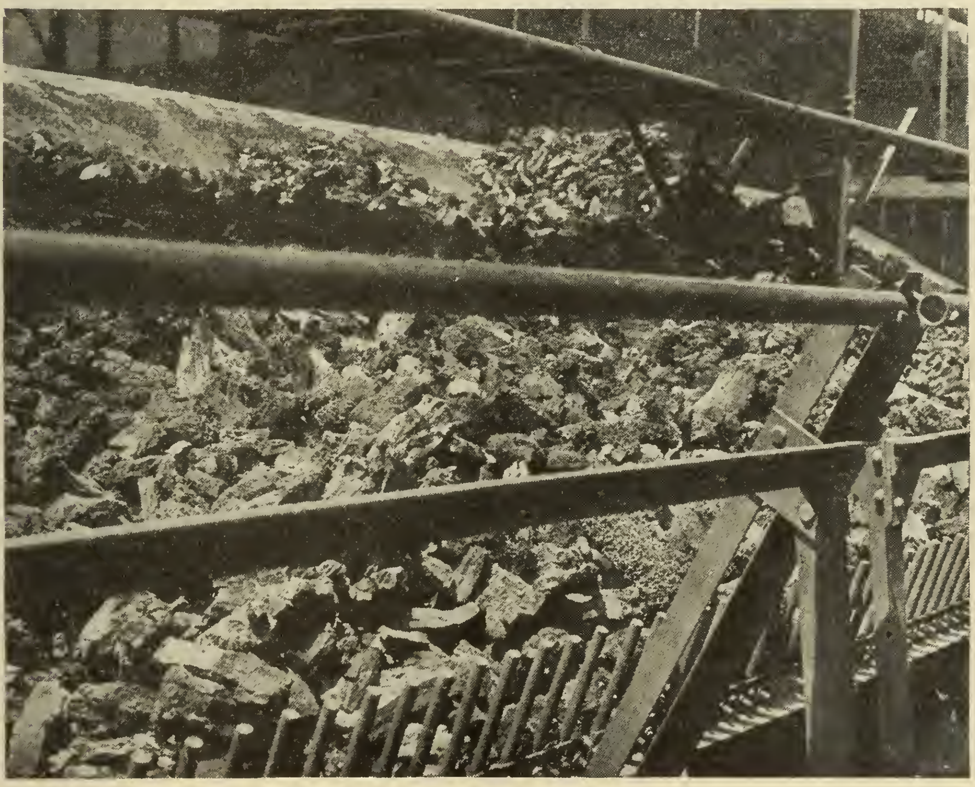
FIG. 30.



60 per cent. high volatile + 40 per cent. Pocahontas.

However, for each kind of coke there is evidently some limiting size for efficient service, *i.e.,* just large enough to offer such a minimum surface of attack for CO_2 that the loss on this account is negligible, and small enough so that complete combustion may be effected in a minimum of time at the tuyères. Hardness of body is usually—though possibly not necessarily—proportional to the resistance of a given coke to oxidation by CO_2 or oxygen. The harder grades of coke should be used in smaller sizes—and this is a compensation automatically provided to some extent by the operation of the by-product oven. Similarly, cokes of close cell structure are more resistant to oxidation, but this may be offset to a large extent by softness. The coke of more open cell structure will probably require less rigid attention to sizing than the denser coke. The important thing is to determine the practical limits of these elements of size, hardness, and cell structure. It may be found that a coke of such structure as No. 1 of our scale may be unsuitable, no matter what may be its size or

FIG. 31.

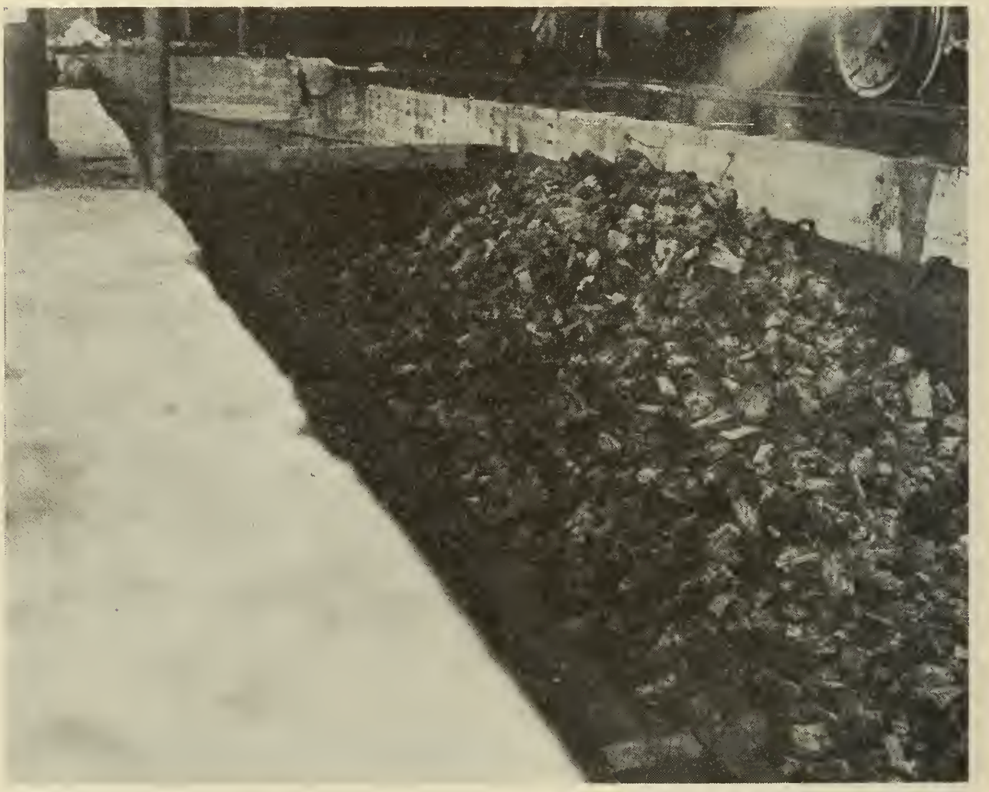


Coke from Colorado coal, showing sponge.

softness; but this ought to be proved by actual test and not taken for granted.

These considerations are of the utmost importance and encouragement to the coke-oven man, because, with a reasonable choice of coal, his control over the quality of his coke is almost unlimited, and, even with a very restricted source of supply, the possibilities of conforming to the desired standard by proper oven construction and regulation are still remarkably great. We propose to conclude this paper by showing two or three examples of what can be accomplished in the way of control of this sort.

FIG. 32.

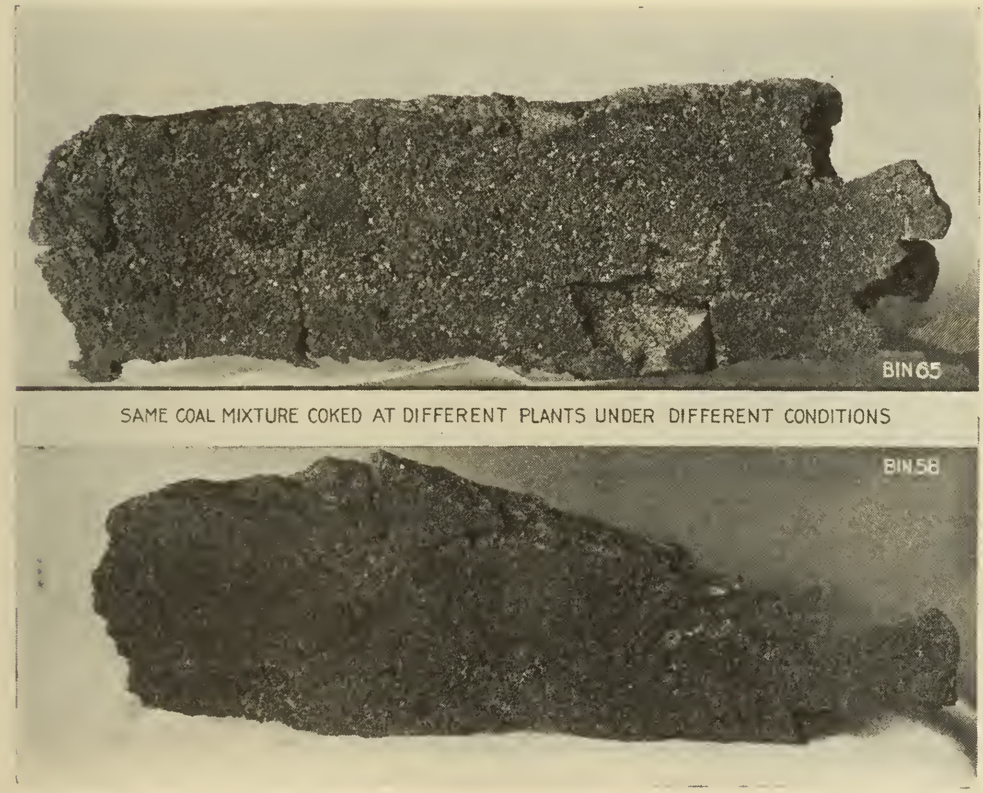


Coke from same coal as Fig. 31, properly made.

One proposition that frequently presents itself is that of eliminating sponge. Sponge is a characteristic honeycombed mass formed in the centre of rich volatile matter. It seems to be caused by an excess of pitchy material moving along with the fused zone in the coking process, and finally accumulating in the centre of the oven, where it is eventually gasified, with the production of this light porous material. Sometimes this sponge is found in loose, detached masses scattered all over the coke as it lies on the wharf after quenching, or, again, it may be found adhering very closely to the ends of the pieces of coke, and sometimes blending, without any clear line of demarcation, into the body of the coke itself.

Although the amount of this sponge often appears to be very large, it is so bulky that its actual percentage by weight is small.

Fig. 33.



SAME COAL MIXTURE COKED AT DIFFERENT PLANTS UNDER DIFFERENT CONDITIONS

In one case where the amount of sponge seemed to be very large it was actually found that it amounted to 1.65 per cent. of the total coke. Small amounts of sponge probably do no harm, most of the material being soon broken up in the operations of handling the coke, but the presence of the material undoubtedly occasions a certain loss of carbon, and so we usually try to get rid of it. The customary remedy—and one that always works—is to mix with the high volatile coal sufficient low volatile coal which has the effect of absorbing the excess of bituminous material and eliminating the conditions of sponge formation. Pocahontas coal is the standard low volatile coal that is employed by many of our plants. It is to be noted that different coals require considerably different percentages of Pocahontas coal to completely eliminate the sponge. Fig. 26 shows a coke from unmixed high volatile coal (about 34 per cent. volatile matter). A large amount of sponge is readily apparent. Fig. 27 shows the coke from a mixture containing 80 per cent. of this same coal with 20 per cent. of Pocahontas. The sponge is entirely eliminated and the structure of the coke improved. Fig. 28 shows coke made from a mixture of 90 per cent. of another coal, containing approximately the same percentage of volatile matter, with 10 per cent. of Pocahontas. This shows a fairly large amount of sponge. A mixture of 70 per cent. of this coal with 30 per cent. of Pocahontas still produces some sponge (Fig. 29), and it required as much as 40 per cent. Pocahontas (Fig. 30) to eliminate the sponge entirely.

Frequently it is too expensive a proposition to buy low volatile coal for the sake of eliminating a little sponge, and sometimes the low volatile coal may be altogether inaccessible for practical purposes. This does not, however, leave us at the end of our resources. By proper methods of control sponge may be eliminated from a wide variety of coals that produce it under ordinary conditions. If the oven is correctly designed and proportioned, and the temperature and coking time carefully regulated, very satisfactory results may be obtained without the necessity of making a special coal mixture. Fig. 31 shows the coke from one coal which was made in a type of oven unsuited to it, and coked at unfavorable temperatures. Fig. 32 shows coke made from the same coal under proper conditions. The sponge has been entirely eliminated.

Occasionally one of the most difficult problems to be overcome is that of too great density of cell structure. Here, again, we can approach the problem in two ways: one, by mixing in one or more other coals that have a tendency to the production of a more open cell structure, and the other way by suitable preliminary preparation of the coal, careful heat control, and special design of the oven. Fig. 33 shows coke made from the same coal mixture coked at different plants under different conditions. The dense coke shown in the lower part of the figure was greatly improved upon when the nature of the coal was better understood, and the excellent product shown in the upper part of the figure was then made when the coal was treated in the right kind of ovens and under proper conditions.

To insure the best results, a special study must be made of each kind of coal that it is proposed to use, and it would be well, in all cases where a new plant is contemplated, to make this study previous to a design of the plant, because the results may suggest some necessary changes in design that would not otherwise be foreseen.

Notes on the Merchant Submarine Deutschland. ANON. (*Scientific American*, vol. cxvi, No. 6, p. 151, February 10, 1917.)—The policy of secrecy which the owners of the merchant submarine *Deutschland* have followed was suspended in the case of the marine artist, Mr. Henry Reuterdahl, when he was permitted to make sketches of the interior. The following notes are based on observations made by Mr. Reuterdahl during his several hours' visit aboard the vessel:

The *Deutschland* is 230 feet in length and is built on the usual system of a circular hull proper, with what might be called an enlarged false hull outside of this. The beam of the hull proper is 17 feet; the full beam of the ship, out to out, is about thirty feet. She is driven by Diesel engines developing 1200 horsepower. The engines have six cylinders and are arranged two on each shaft. The speed on the surface is 14 knots, and submerged 7½ knots. The time consumed in submerging from surface conditions is two minutes. According to Captain Koenig, the total distance run under the submerged condition on the last trip from Germany was 180 miles. American shipping men and naval architects estimate her cargo capacity at 750 tons; according to Captain Koenig, it is 1000 tons. The entire crew, with officers, consists of 29 men.

The conning tower, according to Mr. Reuterdahl, is superior to the type used on our submarines. It carries no loose gear (collapsible surface material) which must be removed previous to diving. The *Deutschland*, like all the later German submarines, is always ready for submergence. The removal of the repeater compass in the conning tower and closing the hatch are all that is necessary. Steering is done from the conning tower, where large ports give clear all-round vision. The German conning towers are large enough to hold four men. When the vessel is submerging, the conning tower is cut off by closing a hatch between it and the interior.

The periscopes, of which there are two, are of great power and remarkable clarity, and in these respects are superior to American periscopes. The periscope in the conning tower is hoisted and lowered electrically; that in the operating compartment is hoisted by a chain-drive operated by hand. None of our own submarines have housing periscopes. The *Deutschland's* periscopes, it is stated by Mr. Reuterdahl, are of much greater efficiency than those on our submarines, and the difference in clarity of vision is something that must be tested to be appreciated.

The principal arrangements for air control and the working of the various tanks are about the same as in the American navy. Those American officers who visited the *Deutschland* were impressed with the high-class workmanship apparent, particularly of the engines and air compressors. There is nothing about the vessel to indicate that it was built during the rush of war time: every part is as carefully finished as would be expected in normal conditions. A peculiarity of construction is that there is no ventilation cowl or funnel to supply air for the Diesel engines. By an ingenious method the conning tower is so arranged that air vents open and close automatically the moment the ship emerges or submerges. The deck is flush and clear of gear of any kind, pockets being provided for the reception of masts, anchors, etc., the former being raised and lowered by quadrants at their lower ends operated by electric motors. A small lifeboat is secured to the superstructure.

A Bibliography of Alloys. C. ESTES. (*Metallurgical and Chemical Engineering,* vol. xvi, No. 5, p. 273, March 1, 1917.)—The study of alloys in a systematic way began in the latter part of the nineteenth century, coincident with the introduction of the pyrometer and the microscopic examination of metals. The introduction of these instruments made possible a much more exhaustive study of the equilibrium diagrams of alloys. Because of the many requirements for alloys with special properties, a complete systematic study of the equilibrium diagrams of alloys should include at least the following investigations for each member of the series: (1) Thermal equilibrium, (2) thermal expansion, (3) thermo-electric force, (4) molecular volume, (5) density, (6) hardness, (7) tensile strength, (8) ductility, (9) electrical conductivity, (10) solution tension, (11) magnetic susceptibility, (12) separation and identification of compounds, (13) microscopical examination, (14) X-ray examination, (15) optical rotation of polarized light from polished surfaces, (16) photo-electric effect, and possibly others.

Various investigators have studied more or less completely practically all of the binary systems of the common metals and a great many of the rarer metals; also about sixty ternary systems and several quarternary systems. A chart of the binary systems investigated is given, immediately followed by a list of references to each system. Separate lists are given for ternary and quartenary systems. The chart is a convenient coördinate arrangement of the metals, opposite any pair of which a key number to the reference list may be found.

THE ELECTRIC STRENGTH OF AIR AND METHODS OF MEASURING HIGH VOLTAGE.*

BY

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AIR AS AN INSULATOR.

NOT only is air a good insulator, but it is one of the very best. It is universally used as such. Practically every electric circuit relies to a greater or less extent upon the insulating properties of the air. The properties of air which make it so valuable as an insulator are its low specific inductive capacity, its very high resistance and its high electric strength or resistance to puncture. Its specific inductive capacity is practically as low as that of any other material and differs very little from that corresponding to the ether. Its ohmic resistance for many years was assumed to be infinite, although we now know from the rate of leak of a charged conductor that it really has an extremely small specific conductivity.

Although the electric strength, or resistance to rupture, of the air was for many years sufficient for all the requirements of electrical engineers, a limit has recently been reached. As voltages for long distance transmission of power have been raised to higher and higher values, it has been found that the air in the neighborhood of the wires breaks down. The phenomenon is visible in the dark as a glow around the wire and is known as the "corona." The glow or brush discharge is confined to the region close to the wire, where the electric intensity is higher than at more distant points. The phenomenon is accompanied by energy loss and this reduces the efficiency of a transmission line.

The value of an electric field at which a break-down of air occurs, and the type of discharge, that is whether spark or corona, depends largely on the shape and size of the electric terminals. Sparks will pass between parallel plates at a field intensity of about 32 kv/cm. Between needle points, spheres and other forms of terminal, the relation of break-down voltage to separation is not regular, and different values of average break-down intensity are met. In these cases the intensity or voltage gradient varies from point to point and the question of break-down seems to involve a relation between the intensity and the volume of the air subjected to this intensity. The matter is further complicated by the fact that the air may be only partially ruptured, forming a brush discharge as observed around needle points and in the corona.

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* Presented at a joint meeting of the Electrical Section and the Philadelphia Section, American Institute of Electrical Engineers, held Thursday, November 23, 1916.

For the reasons mentioned above, simple and symmetrical forms of electrode must be chosen for the experimental study of the electric strength of air. Indeed, only one or two forms of electrode are available. Parallel plates were used by many early experimenters and led to the following law, connecting the separation of the plates X, in centimeters, with the break-down voltage V, in kilovolts.

$$V = 1.35 + 30X \tag{1}$$

This law, however, has never been utilized by engineers as a means of measuring voltage, due to the limited range over which it has been tested and to the difficulties of constructing parallel plates free from sharp edges and from disturbance by surrounding objects.

THE LAW OF CORONA.

By far the most uniform and constant example of the electric break-down of air is the corona on a clean round wire located axially in an outer cylinder forming the opposite electrode. Under given conditions of temperature and pressure, the critical or corona forming voltage in this apparatus repeats itself in successive observations, with a maximum inaccuracy of a fraction of 1 per cent. Moreover, the arrangement lends itself readily to variation of conditions, and experiments with it have led to the law connecting the critical or corona forming electric intensity—E, in kilovolts per centimeter, with the radius of the wire r, in centimeters.

$$E = 32\left(\delta + .296\sqrt{\frac{\delta}{r}}\right) kv/cm \tag{2}$$

The quantity δ is known as the "density factor" and has the value

$$=\frac{3.92p}{273+t} \tag{3}$$

in which p is the pressure of the air in cm. of mercury and t is the temperature, Centigrade. It will be noted, therefore, that at standard conditions δ is equal to unity. The corona *voltage* for any combination of size of central wire and outer cylinder, is calculated from the critical value of E (formula (2)), and the radii of wire and outer cylinder, by well-known relation.

The remarkable constancy and accuracy with which the corona voltage occurs, suggests that it should be a valuable means for studying the nature of the structure of the air. So far, however, it has been practically neglected by experimental physicists. Nearly all of the enormous amount of investigation of the electric properties of the air has been conducted at very low pressures, due to the greatly increased conductivity in that region. The impression has seemed to prevail that, owing to the density of ordinary air, electric and other phenomena are erratic and not suitable for accurate study at atmospheric pressure. The discrete ions of low pressure, which lend themselves so favorably to the development of theory, are supposed to submerge themselves into irregular aggregates at high pressure, thus masking their motion and behavior. The present accepted theory of gaseous conduction, due to Thomson and Townsend, is based wholly on phenomena at low pressures. If this theory is correct, it should explain the clear cut phenomenon of corona and thus secure further valuable support for itself. So far, however, the connection of corona with theory, hangs on the slender thread of one discussion by Townsend.

RELATION OF CORONA TO IONIZATION THEORY.

It will be remembered that the theory of gaseous conduction, as developed by Thomson[1] and Townsend[2] on the substructure of the kinetic theory of gases, conceives the current in a gas to be carried by ions or charged particles of gas. These particles are the negative electron, positively and negatively charged single molecules, or aggregates of molecules with charges of varying magnitude. A break-down or spark-over is due to the progressive generation in the gas of new ions formed from neutral molecules by impact of other ions moving with sufficiently high velocity in the electric field. This conception, first due to Thomson, has been elaborately developed by Townsend under the name "Ionization by Collision."

The single effort to bring corona phenomena into accord with the theory of ionization by collision is also due to Townsend.[3] He assumes that corona is a form of spark discharge and obeys the law of formula (1). Since the observed laws of spark-discharge between parallel plates are in accord with the theory of ionization, so also must corona be in accord with that theory. The assumption enables him to develop theoretically, the relation shown in formula (2), briefly as follows:

With increasing voltage, the diameter of corona increases, and at such a rate that the electric intensity at the outer boundary is always equal to 30 kv/cm., the minimum sparking intensity for air between parallel plates. The mean value between 30 and the electric intensity at the surface of the wire is then substituted for V in formula (1), for the sparking distance between plates, where X is now the radial thickness of the corona. This leads at once to the simple relation between the critical intensity and diameter of the wire first shown by the results of the writer and expressed by formula (2); when δ is taken as unity that is for standard atmospheric conditions.

The influence of temperature and pressure is added by theoretical deduction from the ionization theory that for a round wire in a cylinder the product of radius of wire and pressure is a function of the product of radius of wire and critical electrical intensity, or

$$ap = f(aX) \tag{4}$$

That is, if a and p are varied so that their product remains constant, so also does the product aX remain constant where a, p and X are the radius of wire, pressure of air, and critical surface intensity, respectively. Substitution of this relation in the foregoing leads simply to the complete relation given by formula (2).

There is excellent independent experimental evidence in support of all of Townsend's assumptions, with the single exception of that fixing the outer boundary of corona at the surface corresponding to 30 kv/cm., as calculated from the voltage and dimensions of the wire and surrounding cylinder. Photographic observations by the writer [4] on the diameter of the corona, seem to indicate that the diameter is only approximately that suggested by Townsend. Experiments of this character are, however, difficult, and subject to some uncertainty. A careful study of the potential gradient about a corona-forming wire is greatly needed.

The theory also fails to account for the fact that for the smaller sizes of wire, the surface electric intensity may be raised to values well above 32 kv/cm., without forming corona. This failure is caused by the use of the average electric intensity in the radial thickness of the corona in the first assumption mentioned above. This assumption, therefore, takes no account of the wide difference in the values of the intensity at the surface of the wire and the boundary of the corona.

The sequence of phenomena in the formation of corona would appear then to be somewhat as follows: There are always present in the air a number of free electrons (about 1000 to every cu. cm., or one to each 3.5×10^{16} molecules). Under an electric field, these electrons move and collide with the molecules of the air. If the field is strong enough, the velocity at impact may be sufficient to ionize the neutral molecules and thus form a new electron and a positive ion of about the size of a molecule. If the field is still stronger, the slower positive ions will also begin to form new ions by collision. When this stage is reached, the opposite streams of positive and negative ions generate progressively an increasing number of new ions until the whole gas is saturated, or ionized. This is the phenomenon which is accompanied by the blue glow of an electric discharge, as for example, the corona. Obviously, it starts first at the surface of the corona wire where the electric intensity is greatest. The ions that move outward come to regions of lower intensity and thus lower velocity, and here ions are no longer generated. These moving ions, however, constitute an electric current to the opposite side of the circuit, and it is this current, or leakage, that causes the energy loss in long distance transmission lines when the voltage is raised above that corresponding to the formation of corona. These ions are probably single molecules, or groups of two or three molecules and they move with a velocity of about 1.3 cm. per second per volt per cm. The phenomena, as described, of course take place in extremely short intervals of time, so that observations with continuous and alternating voltages, are in agreement when based on the maximum values of the latter.

THE MEASUREMENT OF HIGH VOLTAGE.

Attention has already been drawn to the extreme constancy of the value of voltage at which corona appears on a clean wire. This fact has often prompted the suggestion that a corona wire be used as an instrument for measuring high voltage. The chief objection has been that for visual observation of the corona, the wire must be viewed in the dark. In addition to this a single wire indicates only one value of voltage, and wires of various diameters must be used in order to extend the range. A corona voltmeter as developed by the writer, which not only avoids the necessity for observation in the dark, but which also is suitable for a wide range of voltage without altering any of the features of the instrument, is described later in this paper. Before describing the corona voltmeter, however, a brief review of other available methods of high voltage measurement is desirable, in order that the improvement offered may be emphasized.

Voltage, or difference of potential, is by definition of the nature of work. Its direct measurement in units of work has probably never been attempted. Difference of potential may be measured in terms of a mechanical force in the so-called absolute electrometer and this is generally spoken of as the absolute measurement of voltage. The method and the instrument are highly elaborate and are rarely used. Practically all present methods of measuring voltage accurately involve comparison with existing standards of voltage, the so-called standard cells. The electromotive force of these cells has in each case been determined, either directly or by comparison, from standards of current and resistance, these standards themselves having their ultimate origin in absolute measurements. The standard cell and the standard resistance are the working standards of to-day, since they are the most convenient, most permanent and most readily reproducible.

Highly developed laboratory methods permit the measurement of continuous voltages of moderate magnitude, say up to 100 or 200 volts, in terms of the standard cell, to a high degree of accuracy. Beyond these values errors arise and the insulation of the apparatus becomes a disturbing factor. Exact measurements of large values of voltage, therefore, are difficult and unusual.

In the case of alternating voltages, the effective values of low voltages may be measured with considerable accuracy. For higher values the transformer offers a simple means of reducing the voltage to the range in which accurate measurements are possible. The accuracy thus depends on the ratio of transformation of the transformer, and in the so-called " potential transformers " this ratio is itself determined very accurately. Potential transformers become heavy and expensive with increasing voltage and are rarely constructed for voltages above 33,000 volts. Furthermore, this method measures the effective value and not the maximum value of the voltage.

Long distance transmission voltages now reach above 200,000 volts and the requirements for experiment and testing have led to the construction of transformers for 500,000 and even 1,000,000 volts. The question of measurement of these high voltages is an extremely important one. From what has been said, it will be understood that there is no method available for more than an approximate measurement of such voltages. The potential transformer, even if constructed for such values, would be almost as large and expensive as the power transformers themselves and would be under grave suspicion as regards the value of the ratio of transformation. It becomes necessary, therefore, to adopt some rougher, more approximate measure of such high voltages. The convenience and accuracy of direct reading scales are no longer available. The puncture of insulation, the spark discharge, and, as later and now especially described in this paper, the corona on round wires, are utilized as measures of the magnitude of voltage. These methods leave much to be desired in the matters of convenience in manipulation and simplicity, but when the difficulties of controlling and handling high voltages are remembered, it will be seen that it is perhaps fortunate that we have methods of measurement even as convenient and as accurate as these. Obviously, the calibration of such instruments is subject to the uncertainties suggested above, pertaining to the accurate measurement of high voltage. A brief description of a new method of calibration and its application to the corona voltmeter will be given later in this paper.

THE NEEDLE GAP AND THE SPHERE GAP.

The American Institute of Electrical Engineers now authorizes in its Standardization Rules two standards for the determination of high voltage. They are the spark gap between needle points and the spark gap between metal spheres 6.25, 12.5, 25 and

50 cm. in diameter. In each case the voltage is determined by the greatest distance of separation at which a spark will pass. Curves are furnished, showing the relation between voltage and the length of gap for each type of instrument. Correction factors are also given for variations of temperature and pressure from standard conditions.

Neither of the above instruments has given satisfaction nor inspired confidence in usage. The necessity of renewing the needle points after each discharge, the errors introduced by the proximity of surrounding objects, and the variation among successive readings, are the chief objections to the needle gap. In addition, there is the necessity for the accurate measurement of the distance between the needle points which involves a micrometer screw, and the setting of a new zero for each discharge. The specifications state that under the best conditions of experiment, a minimum inaccuracy of 2 per cent. is to be expected.

The sphere gap has been adopted as a standard only recently and comparatively few reports of its performance have been published. The possibilities of the instrument were first noticed by Alexander Russell,[5] who made an effort to establish a definite relation between the dimensions of the sphere gap and its spark-over voltage. DeKowalski and Rappel [6] have taken issue with Russell as to the possibility of accurately expressing the electric intensity between spheres, under different distances of separation, although their experimental observations do not differ widely from those of Russell. Recently Chubb and Fortescue,[7] and Peek,[8] in this country, have published results of tests and calibrations of sphere gaps, and one of the larger manufacturing companies now offers the instrument for sale.

The sphere gap is more constant under repeated readings than the needle gap, although it still shows noticeable variations. While it is free of the necessity for a renewal after each discharge, the surfaces of the spheres deteriorate on a repeated discharge and the instrument is sensitive to dust particles, moisture, or other surface irregularities. It is sensitive to the proximity of surrounding objects and its calibration curve is widely different for the cases, both terminals insulated, and one terminal grounded. The calibrations, as determined by different observers, are not in good agreement and the results of a single observer frequently differ by several per cent. The sphere gap shares with the needle gap the disadvantage that the reading of the instrument necessitates a spark discharge from the circuit. The occurrence of such a discharge is frequently objectionable, if not dangerous, on account of the oscillations set up in the high tension circuit. This fact makes necessary the use of a high resistance in series with the gap in each case. This adds considerably to the dimensions and complexity of the instrument, as the resistance must be insulated for the voltage to be measured.

THE CORONA VOLTMETER.

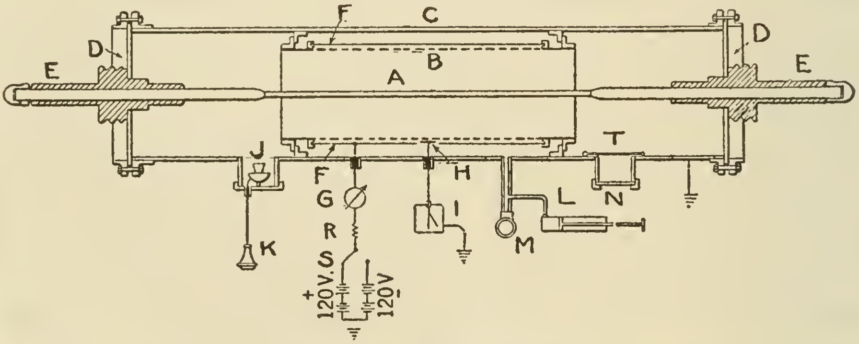
A diagram of the essential elements of the Corona Voltmeter is shown on Fig. 1. The corona forms about the central wire, or rod A, when the potential gradient at the surface of A, caused by the application of voltage between A and the case, reaches the value given by formula (2). The voltage corresponding to this gradient by well-known relations, depends only on the diameters of the rod and the inner cylinders B. As now constructed, the cylinder B is always connected to ground.

The outer cylinder C, which is also connected to ground, encloses the voltmeter proper, consisting of the wire A and the cylinder B and is air-tight. Means are also provided at L for varying and reading the value of the pressure inside C. Provision is also made at T for reading the temperature. For any observed temperature, it is possible, therefore, to adjust the pressure so that any desired value of δ, the density factor of formula (3), may be obtained. By this means the instrument may be set for a wide range of critical corona-forming intensity and hence of critical corona-forming voltages, with only one wire, or rod. This method of setting the instrument for a definite voltage, by varying the pressure rather than by a change in the size of the rod or other dimension, is one of its novel and characteristic features. In a corona voltmeter of range 40,000 to 100,000 volts, the pressure range is that between 60 cm. and 140 cm. of mercury. This range of pressure is readily accomplished with an ordinary hand pump.

' Attention has already been drawn to the disadvantage of the corona as a voltage indicator, imposed by the necessity of viewing it in the dark. It is obvious, therefore, that an instrument which claims superiority over the sphere gap must be free of this objection. The corona voltmeter, as now developed, provides three methods of detecting the initial appearance of corona, in addition to that of visual observation. These methods involve the use of the gold-leaf electroscope, the galvanometer and the telephone.

The corona is a source of copious ionization and if a few small holes be drilled through the cylinder B, and the electrode H, connected to an electroscope, be placed opposite these holes, the electroscope discharges rapidly as soon as corona appears. The relation between them is very sharply marked and the finest adjustments of voltage for the starting of corona bring about simultaneously the discharge of the electroscope. The writer has described in several papers [9] experiments showing that by this means the start of corona may be read to a maximum inaccuracy of ¼ of 1 per cent.

FIG. 1



Corona voltmeter for 100,000 volts—Central section and connections of auxiliary apparatus.

If the entire surface of the cylinder B be drilled with holes, and an insulated outer cylinder or electrode F completely surround B, a much greater volume of ionized gas may be utilized if this outer cylinder be also connected to ground through a galvanometer and a battery or other source of continuous potential difference. The galvanometer serves as an excellent indicator of the beginning of corona. No current flows until corona forms and then a sensitive galvanometer shows a sharply marked deflection. A portable needle galvanometer of sensitivity 10^{-5} amp. has been used, but a somewhat greater sensitivity than this is desirable.

In the open, the corona emits a low, hissing noise, but when confined by such an outer casing as C of Fig. 1, the sound is gathered and has considerable volume when the ear is placed at an opening in C. There is no sound before corona begins, and the smallest possible corona gives a sound amply loud for using this method as a detector. As the pressure in C must be varied in order to obtain the range of the instrument, it is not possible to have any openings in it. For this reason, in order to use the sound of the corona as a detector, recourse is had to a telephone transmitter and receiver, as shown in Fig. 1 at J. The arrangement works perfectly and the telephone is perhaps the most convenient and satisfactory of all the methods of detecting the corona. One of its advantages over the galvanometer and electroscope is that it will detect surface irregularities on the corona wire by the characteristic sound of the small sparks which are peculiar to such irregularities.

In normal usage, the usual requirement of a high voltage indicator is that it should be set for a definite voltage, for the purpose of insulation testing, and the like. In the case of the needle gap and sphere gap, this is accomplished by means of the micrometer screw heads, which are set for a certain separation, determined after measuring the temperature and pressure of the atmosphere, and applying the corrections which are given in the tables or curves which accompany the instruments. In the corona voltmeter, no correction factors are necessary. To set the corona voltmeter for a definite voltage, the temperature is read on a thermometer furnished with the instrument and a pressure corresponding to this temperature and the required voltage is read off from a table of values, or a curve. The only adjustment of the instrument which is necessary is to compress or exhaust, by means of a hand-pump, the air in the instrument to this pressure, as indicated by a pressure gauge. The voltage is then raised until corona is formed, as indicated by any one of the methods already described. The voltage may be raised to this value and lowered as many times as desirable, without resetting of pressure or any other adjustment.

For reading an unknown voltage, it is only necessary to set the pressure in the instrument to a value known to correspond to voltages higher in value than that to be measured. The voltage is then applied and then air pressure in the instrument allowed to fall slowly, by leakage through a small valve, to such a value that corona just begins. The value of pressure, together with the temperature in the instrument, will give, by means of the curves or table, the unknown value of voltage. The corresponding operation in the sphere gap or needle gap involves the repeated opening of the high voltage terminals and the setting of the gap between each pair of readings to shorter and shorter values, until one is reached at which the spark passes. This is a very tedious operation and requires much time.

CORONA VOLTMETERS FOR 50,000 VOLTS AND 100,000 VOLTS.

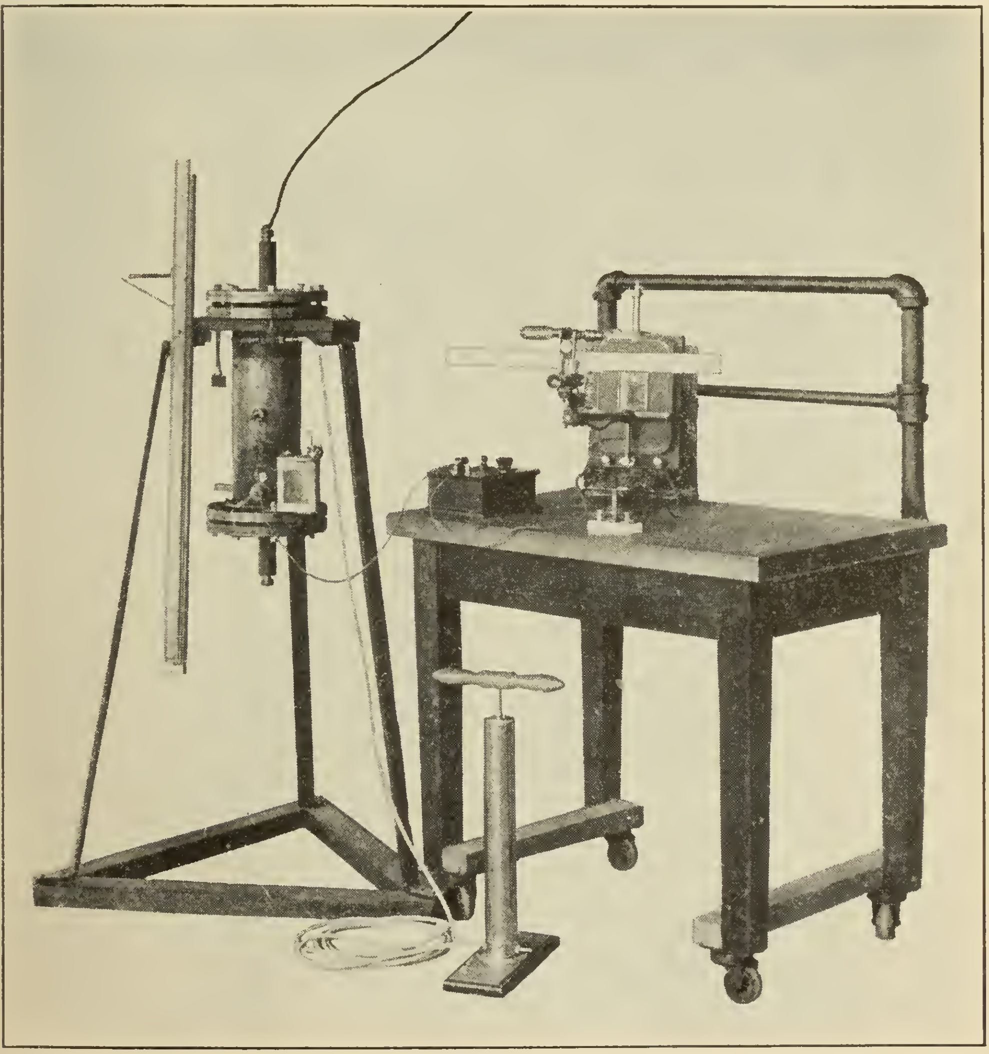
Up to this time the corona voltmeter has been constructed in two sizes, for voltages up to 50,000 and 100,000, respectively. These two instruments are shown in Figs. 2 and 3, which also show the auxiliary equipment for the use of the electroscope, galvanometer and the telephone, as detecting instruments. The pressure and vacuum pump is also shown. In the smaller instrument, the diameter of the inside, or corona, cylinder is 9.51 cm. and its length 25 cm. The corona wire, or rod, is of nickel-plated tool steel .396 cm. in diameter. This instrument is readily portable, weighing about 75 pounds. In the larger instrument, the diameters of rod and cylinder are .635 cm. and 30.7 cm., respectively, and the length of the inner cylinder 92 cm. Both types of instrument have been described in detail in a paper [10] before the American Institute of Electrical Engineers, which also gives the results of a number of tests of their constancy and permanence. The extreme range of air pressure in the outer cylinder necessary for the voltage ranges 20,000 to 50,000 volts, and 40,000 to 100,000 volts is that between 40 and 140 cm. of mercury.

Considering the possible range of voltage for a single corona voltmeter with only one size of corona wire, or rod, it is obvious that a much wider range of pressure than that mentioned above is readily possible. Such a wider range of pressure would, of course, lead to an extension of the voltage range. In the instruments shown in Figs. 2 and 3, the upper limit of voltage has been found in the insulating bushing leading the voltage to the corona-forming wire. Brush discharge takes place over these bushings, as constructed, if the voltage is carried above the upper values which have been given. In both cases, however, these bushings were of experimental construction and there is possibility of considerable improvement. An instrument is now in process of construction which has the general design shown in Fig. 4. In this case only one bushing is used and this has been especially designed for the conditions met in the corona voltmeter.

It is certain that the use of this bushing will permit much higher values of voltage and hence a wider range for the instrument than that already mentioned.

In the new form of instrument, the lower end of the corona rod will be supported by a metal sphere, mounted on top of a post or pedestal type insulator, as indicated in Fig. 4. This insulator is of porcelain, and is of simpler construction and less expensive than a bushing. The metal spheres on the pedestal insulator and also at the lower end of the bushing are for the purpose of avoiding sharp edges and so preventing regions of high electric in-

FIG. 2

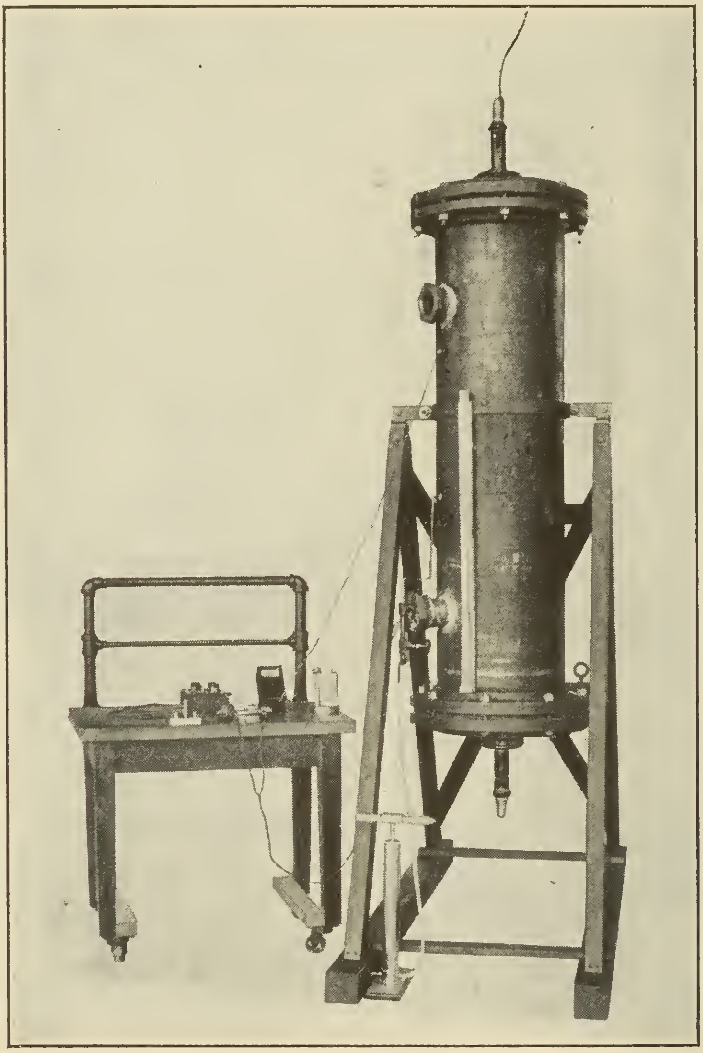


Corona voltmeter for 50,000 volts.

tensity which might cause corona, or spark-over, before corona forms on the central conductor.

Experiment has shown that a corona wire maintains its surface without deterioration through a very great number of tests; in fact, a moderate corona may be maintained continuously for a considerable length of time on a nickel-plated corona rod, without impairing its surface to any appreciable extent. In time, however, it does become necessary to remove and clean the corona rod. It may also be desirable to change the rod to one of a different diameter, in order to vary the range. It is important

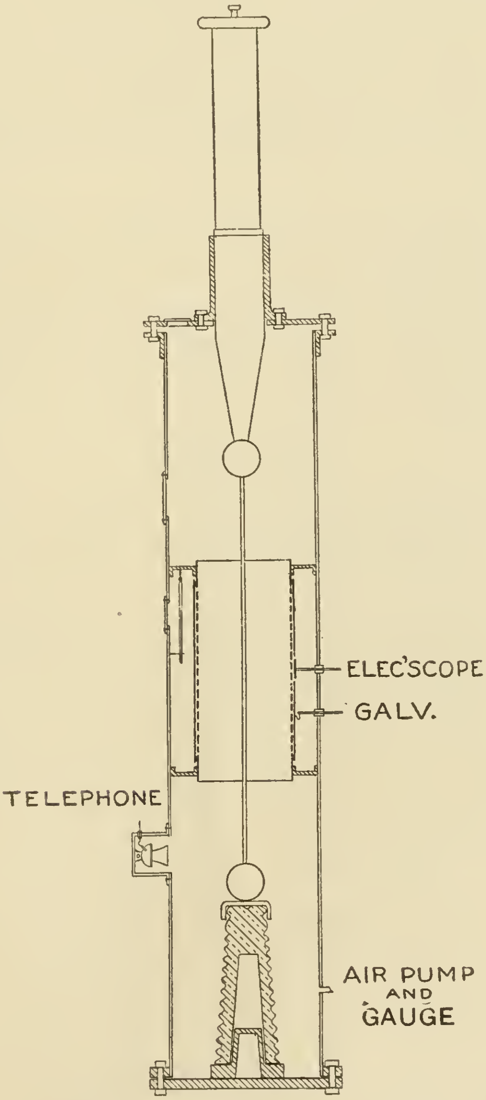
Fig. 3



Corona voltmeter for 100,000 volts.

that these changes may be made as quickly and easily as possible, and for this reason a small opening is provided in the top end-plate of the voltmeter through which a rod may be removed or inserted. This operation is further assisted by the presence of two hand holes in the sides of the cylinder, directly opposite the points of support of the corona rod. The several rods of one instrument are similar in all respects, except as to diameter, and they fit readily into a receptacle in the top of the lower sphere and also into a split fitting on the bottom of the upper sphere. These

FIG. 4



Corona voltmeter for 150,000 volts.

spheres being rigidly in place thus provide for the accurate centering of the rods.

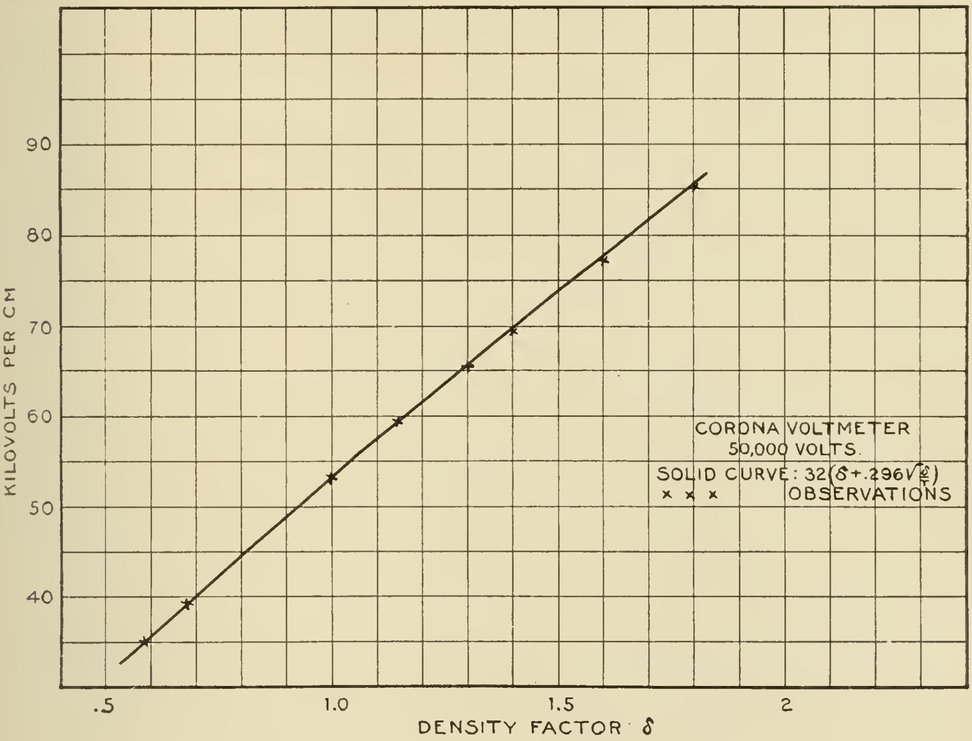
The voltage at which corona forms on a clean round wire is independent of the moisture content of the air, consequently no determination of the moisture content, nor correction for variation in the moisture content, are necessary in the corona voltmeter. This is an extremely important fact, as, if it were not so, the operation of the instrument would be so complicated as to render it unsuitable for any but laboratory conditions, since the control and accurate determination of the moisture content of air are very difficult.

The corona forming voltage is also independent of the frequency within very wide limits. Careful experiment has shown that the laws which have been given are obeyed up to 3000 cycles. No correction, therefore, for frequency is necessary in the use of the corona voltmeter for all present day commercial frequencies.

CALIBRATION.

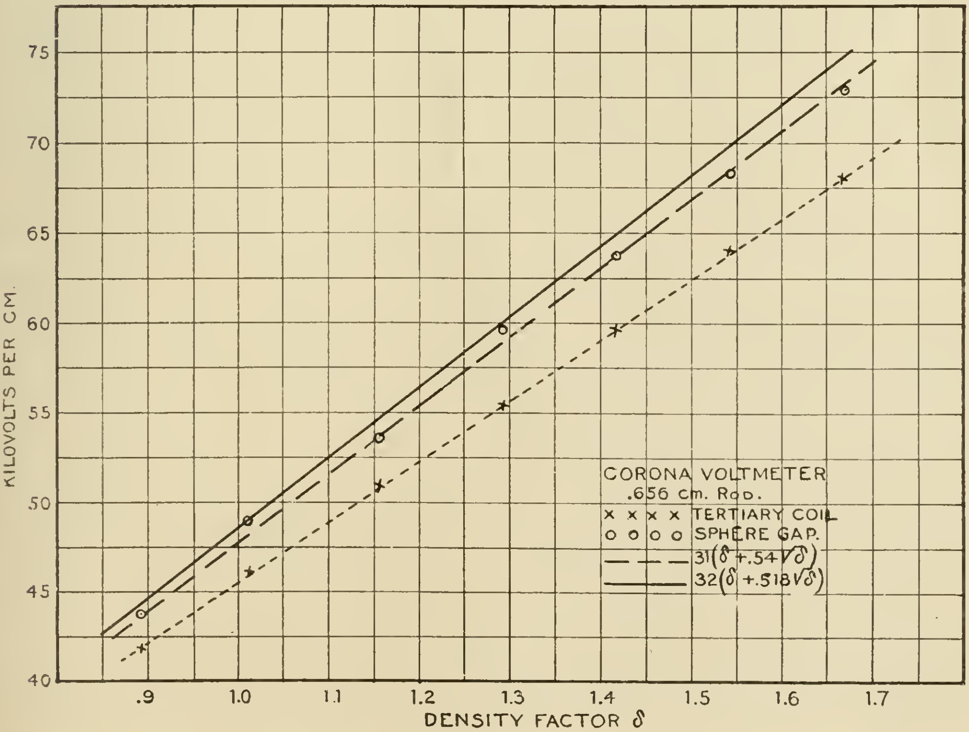
Attention has already been drawn to the fact that the corona voltmeter has an inherent calibration, depending only on its dimensions and on the density of the air. This calibration, which is one of its most valuable features, is obtained from the relation shown by formula (2), giving the critical, or corona forming, electric intensity at the surface of the corona rod. The constants in formula (2) are those which have been determined by the writer. Other experimenters have also made determinations of these constants and all of the values are in very close agreement. These constants, for the most part, have been determined by experiments with alternating voltages and the measurements made on the low voltage side of a step-up transformer, using the ratio of the numbers of turns in the high voltage and low voltage windings as a multiplying factor. The maximum values of voltage have also been determined by wave-form measurements on the low voltage side of the transformers. This method is probably very accurate up to values of voltage in the neighborhood of 30,000 volts. With higher values of voltage, however, the electrostatic capacity of the high voltage transformer winding and of the corona voltmeter, in combination with the leakage reactance of the transformer winding, lead to greater or less error and uncertainty.

FIG. 5



Calibration of corona voltmeter, 50,000 volts.

FIG. 6



Calibration of corona voltmeter, 100,000 volts.

Methods for the accurate determination of voltage directly in the high tension circuit have never been developed. For this reason, the calibration curve of the corona voltmeter for high values of voltage can only be obtained by the extension of the relation shown in formula (2) to such higher ranges. Fig. 5 shows the calibration curve of the smaller of the instruments described above. It will be noticed in this curve that the readings of voltage, as calculated from measurements on the low tension side by the method described, coincide almost exactly with the calculated curve throughout the whole range, except at the higher values. In this region the errors due to the leakage reactance begin to appear. The direction of this error is always such that a higher voltage exists at the high tension terminals than is indicated by the voltmeter measurement on the low tension side. This accounts for the lower readings indicated in the upper region of the curve.

In the larger instrument, the error becomes even greater, owing to the larger capacity of the instrument and to the higher voltages. The comparison between the inherent calibration curve, as calculated from formula (2) and the observed readings is shown in Fig. 6, where the latter fall very markedly below the inherent calibration curve. Fig. 6 shows also the results of some comparative tests with the sphere gap. The sphere gap readings are also seen to fall below the inherent calibration curve. Attention may also be drawn to the greater regularity of the corona voltmeter readings, as compared with those of the sphere gap.

A METHOD FOR DIRECT MEASUREMENT OF HIGH VOLTAGE.

A method for determining directly, without the intermediation of a transformer, the voltage of a high tension circuit, is much needed. Experiments are now under way, by the writer and his associates, working to the development of such a method. The plan in brief is to construct an absolute electrometer, suitable for use directly in a 100,000 volt circuit. This instrument will read the effective value of voltage. In order to determine the maximum value, it is purposed to determine the wave-form in the high tension circuit by series connection of a number of air condensers, taking the wave-form across a small portion of the total series-connected capacity and in the neighborhood of ground potential.

With the development of an accurate method of direct determination of the high voltage, such as mentioned in the foregoing paragraph, it should be possible to determine definitely, and beyond dispute, the constants of formula (2). When this is done, there will be available a new absolute standard of high voltage. Further, it will be possible to construct a standard voltmeter, which may be readily adapted to present commercial needs in the testing of insulation and other cases in which accurate measurement is desirable.

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The Tungar Rectifier. R. E. RUSSELL. (*General Electric Review,* vol. xx, No. 3, p. 209, March, 1917.)—The name "Tungar" is applied to a hot cathode argon-filled rectifier developed by the research laboratory of the General Electric Company. It has been known for a number of years that a vacuum tube containing a hot and cold electrode acts as a rectifier. Rectifiers utilizing this principle were not practical for many reasons. More recently this principle has been employed in the Kenotron, a rectifier of very high voltages, and also in the Coolidge X-ray tube. These two devices depend for their operation upon the emission of electrons (small particles of negative electricity) from an incandescent filament. In the Kenotron and Coolidge tubes there is the highest possible vacuum, so that the electrons themselves are the only current carriers, and the tubes operate at low current and high voltage. In the Tungar rectifier bulb there is an inert gas at low pressure, which is ionized by the electrons emitted from the incandescent filament. This ionized gas acts as the principal current carrier, with the result that the bulb operates with a very much lower voltage drop (5 to 10 volts) and is capable of passing a current of several ampères, the current limit depending upon the design and size of the bulb. The bulb in general appearance is not unlike a modern gas-filled, coiled-filament incandescent lamp with a third terminal carrying a graphite electrode of relatively large cross-section opposite the customary screw socket to which the terminals of the helical filament are attached.

The bulb rectifies for the reason that on the half cycle, when the incandescent tungsten filament is negative, the electrons from it are being pulled toward the anode by the voltage across the bulb, these electrons colliding with the gas molecules and ionizing them; that is, making them conductive in the direction of anode to cathode. At the same time, on the other half of the cycle, when the filament is positive, any electrons that are emitted are driven back to the filament, so that the gas in the bulb is non-conductive during the half-cycle.

At the present time Tungar rectifiers of the half-wave type are available in three capacities on a 115-volt, 60-cycle circuit: (1) a two-ampère unit for charging three cells at two ampères, six cells at one ampère, and eight cells at 0.75 ampère; (2) a six-ampère 7.5/15-volt unit for charging three or six cells at six ampères; (3) a six-ampère 7.5/75-volt unit for charging three to thirty cells. The bulb life, it is believed, will average 600 to 800 hours. The efficiency compares favorably with other reliable devices of similar capacity, the six-ampère 75-volt rectifier having an efficiency of 75 per cent. when delivering its full output of 450 watts. Work is rapidly progressing on full-wave rectifiers for larger capacities and for telephone or other service where the half-wave cannot be used.

Standard Widths for Wagon Tires. E. C. McCORMICK. (*U. S. Department of Agriculture, Circular No. 73,* February 12, 1917.) —The Office of Public Roads and Rural Engineering has conducted a series of tests, extending over several years, to determine the traction per ton of total load on tires of various widths suitable for use on country roads of earth and gravel, as well as those of a more improved type. In conducting these experiments the road was prepared by plowing up, grading, and rolling prior to each test, so that the condition of the road at the beginning of each test was as nearly uniform as it was possible to make an earth road. The trips selected for comparison are those in which moisture and atmospheric conditions were practically identical.

With a gross load of 5000 pounds the unit draft decreases with the width of tire up to and including a width of 5 inches. For a 6-inch tire the draft increases, indicating that there is no advantage in increasing the width of tire beyond a certain point. A standard road roller carries a load of 450 pounds per inch of width, and it is not considered advisable to employ this unit of load in any vehicle. For the usual types of wagons employed in farming operations and all general work except the heaviest trucking and certain specialized hauling, the following widths of tires are recommended for various capacities: One-horse wagon, 2000 pounds gross load, 2 inches width of tire; light two-horse wagon, 3500 pounds, 2½ inches; medium two-horse wagon, 4500 pounds, 3 inches; standard two-horse wagon, 6800 pounds, 4 inches; heavy two-horse wagon, 7500 pounds, 5 inches.

THE COLORS OF MOTHER-OF-PEARL.*

BY

A. H. PFUND.

At the request of the U. S. Bureau of Fisheries the following work was undertaken to ascertain the cause of the iridescence of mother-of-pearl. While numerous investigators have studied this problem, their results have been largely of a qualitative nature. Probably the first in the field was Sir David Brewster who, as early as 1853, arrived at conclusions which are in substantial agreement with those held to be correct at the present day. As a result of the present investigation quantitative measurements, substantiating the original conclusions of Brewster, are presented. These results are made possible in consequence of extending the observations into the infra-red region of the spectrum where conditions are much simplified. Incidentally it is shown that much information on this subject may be gained entirely without the use of a microscope.

By following the course of procedure to be outlined it is possible to subject almost the entire surface of an iridescent shell to study. Since, however, the primary purpose of this work is to ascertain the cause of iridescence it was deemed advisable to confine the investigation to clear-cut cases, therefore specimens of shell showing extremely brilliant colors were chosen. Since these specimens formed parts of ornamental pictures and jewelry it is out of the question to ascertain the types of shell from which the specimen were taken.

STRUCTURE OF SHELL.

The structure of the shell of a fresh-water mussel (Abovaria ellipsis (Lea)) is shown in Fig. 1.[2] This is a perpendicular section of the shell (near its growing edge) and shows the disposition of the various layers. Roughly speaking, the shell may be said to consist of three layers:

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* Communicated by the Author.

[1] "Optics," by Sir David Brewster (1853), pp. 137–149.

[2] Drawing prepared by Dr. R. E. Coker.

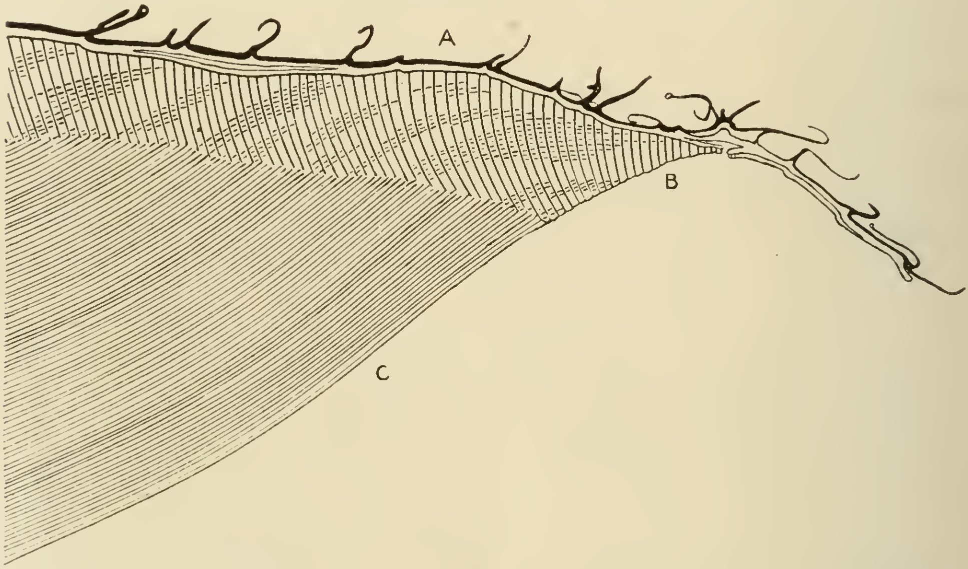
1. An outer horny layer (*a*) (periostracum) which is composed of organic matter (conchiolin).

2. An intermediate layer (*b*) of minute prisms of $CaCO_3$ separated by thin layers of conchiolin. This layer is termed the "prismatic layer."

3. An inner layer (*c*) composed of alternate laminæ of $CaCO_3$ and conchiolin. This is the true mother-of-pearl or "nacre."

That minute layers of conchiolin exist between those of $CaCO_3$ is shown by placing a shell in hydrochloric acid. The calcium carbonate disappears, leaving a flabby, honeycombed mass mass of conchiolin in practically, the form of the original shell.

Fig. 1.



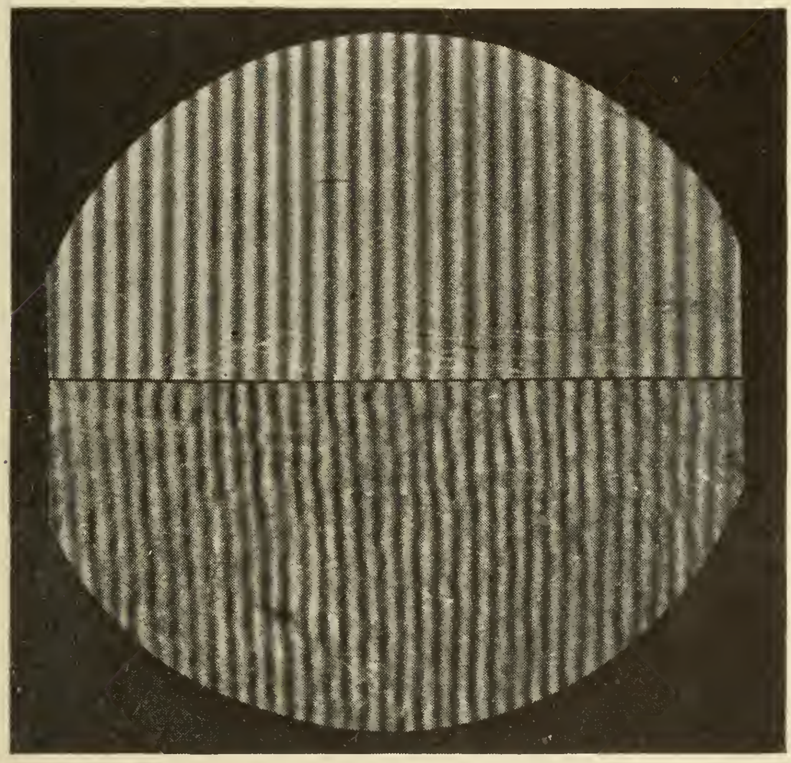
Diagrammatic camera lucida drawing of section of fresh-water mussel shell (Abovaria ellipsis (Lea)).

DIFFRACTION COLORS.

Whereas the minute layers of nacreous matter are continuous on the inside of the shell, they terminate abruptly on the outside. Each layer projects slightly beyond the edge of its predecessor hence the outside of the nacreous portion will show innumerable steps or ridges running parallel to the growing edge of the shell. Such a surface structure is identical with that of a diffraction grating, hence, in case the spacing is sufficiently regular, diffraction colors might be looked for on the outside of a shell.

In order to study these colors it is first necessary to grind off the horny and prismatic layers and polish the nacreous layers by means of a buffing wheel. By permitting the light from an incandescent lamp to be reflected from this surface, pure diffraction colors are observed. As a rule these colors are rather inconspicuous since they are masked by the flood of light coming from the underlying portions. These phenomena may be studied most readily by means of celluloid copies or replicas which are made by flowing celluloid dissolved in amyl acetate over the surface of the shell. After the amyl acetate has evaporated the shell is immersed in water for about 20 minutes. The celluloid is then removed and dried on a plate of clear glass.

FIG. 2.
Rowland grating. 7230 lines per inch.



Shell
9000 lines per inch.

A microphotograph obtained from such a replica is shown in Fig. 2. For the sake of comparison a similar photograph of a replica taken from a Rowland diffraction grating having 7230 lines per inch, is shown. Since the scale of enlargement is the same in both cases it appears that the steps or ridges on the outside of the shell are spaced at the rate of about 9000 per inch. This particular shell belonged to a mussel taken from the Mississippi River. As might be expected replicas taken from the inside of the shell revealed no grating structure.

It is obvious that the microscope may be dispensed with entirely in a study of the spacing of these lines for, by measuring the angle of diffraction of light of known wave-length, the grating space may be obtained at once. If a piece of cardboard with a pin-hole 0.5 mm. in diameter be placed in contact with the replica and if a Nernst lamp be viewed through this opening, the two first order diffraction spectra may be seen. If the pin-hole be moved perpendicular to the direction of the lines a study may be made of the striking periodicities in the spacing of the lines. At intervals the lines will be spaced at the rate of 6–8000 lines per inch while the regions in between will show a spacing of 15–20,000 lines per inch. This is not the place to discuss the question as to how these layers are deposited by the living mussel or what the cause of the periodicity giving rise to layers of such remarkable uniformity is. Yet, a study of these questions might be much facilitated by the use of replicas which, when viewed in the white light from a small, intense source, show extremely brilliant colors and color changes over the surface, thus enabling one to tell at a glance where the spacing is coarse or fine.

INTERFERENCE COLORS.

Upon grinding the surface of mother-of-pearl with fine emery all traces of diffraction colors disappear and the brilliant iridescence alone remains. These colors can, obviously, be due only to interference in the parallel laminæ. A rough test of this inference consists in reflecting light almost normally from a patch on the shell appearing red. By increasing the angle of incidence and moving the eye so as to receive always the reflected beam, the color changes in succession to orange, green, and finally blue. The same phenomenon is observed with Lippmann color-photographs and crystals of $KClO_3$ whose structure is known to be laminar. In order to prove even more conclusively the correctness of this explanation, white light of great intensity was reflected from the mother-of-pearl into a spectrometer and, by means of suitable apparatus, the intensity of the radiation in the near infra-red and visible spectrum was studied with the view of finding indications of interference maxima.

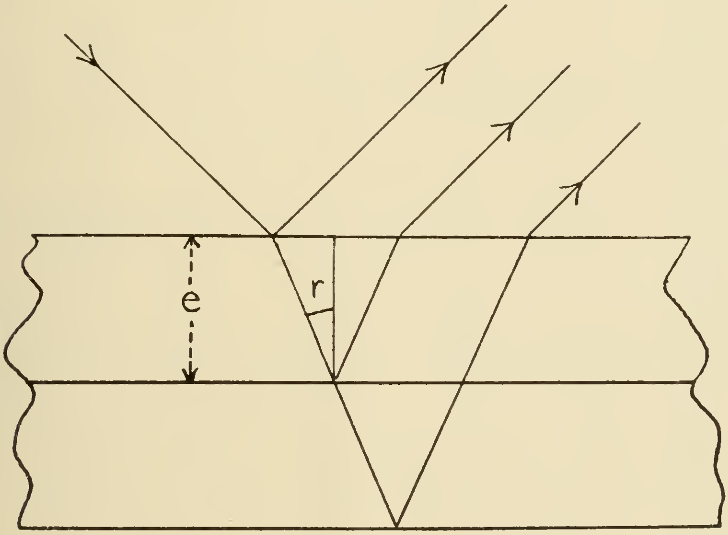
In Fig. 3 the parallel layers of $CaCO_3$ separated by extremely thin films of organic matter are shown. An incident beam of light suffers successive reflections at the various surfaces, each beam lagging behind its predecessor by an amount

$$\Delta = 2\mu e \cos r$$

where μ = refractive index
e = thickness of layer
r = angle of refraction.

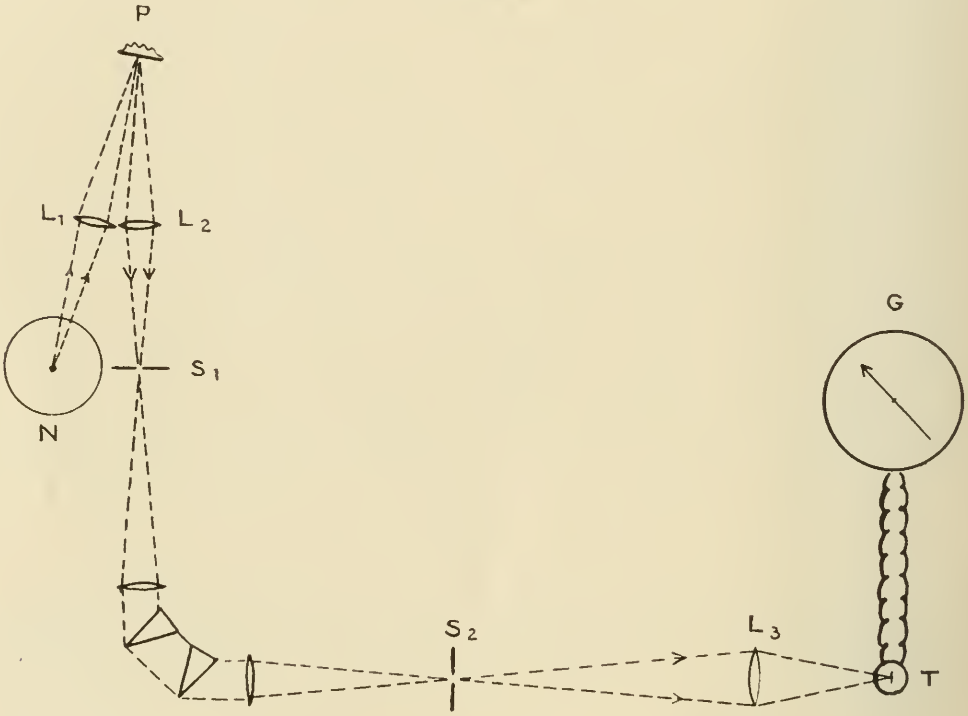
Since conditions under which the successive beams are reflected are the same, the phase-change occurring at reflection need not be considered. It is evident that constructive interference will take place whenever $\Delta = \lambda_1, 2\lambda_2, 3\lambda_3$, where $\lambda_2 = \frac{\lambda_1}{2}, \lambda_3 = \frac{\lambda_1}{3}$, etc. If, therefore, the reflected light should show maxima at the wave-lengths $\lambda_1, \frac{\lambda_1}{2}, \frac{\lambda_1}{3}$, etc., the conclusion may be drawn that interference between parallel laminæ is the cause of the phenomenon.

FIG. 3.



The arrangement of apparatus used in this experiment is shown diagrammatically in Fig. 4. An image of the straight coil of incandescent tungsten wire in the gas-filled lamp N was projected on the surface of a polished bit of mother-of-pearl P. This was so adjusted that a beam of brilliantly colored light fell upon the lens L_2 which focused the light on the primary slit of a monochromatic illuminator I. The monochromatic radiation leaving the secondary slit was focused on the vacuum thermocouple T, connected to a D'Arsonval galvanometer G. Without exception the laminæ in the mother-of-pearl made a small angle with the outer surface, hence the surface reflection was not superimposed on that coming from the laminæ. Since the galvanometer deflections had been shown to be proportional to the intensity of the radiation falling on the thermocouple, such deflections were recorded in the wave-length interval extending from .5μ (visible green) to 2.5μ (infra-red). On account of the lack of planarity of the laminæ no absolute determination of the percentage of energy reflected could be made. Yet by substituting for P a fresh surface of polished silver and by carrying out a similar set of measurements, it was possible to obtain relative values of the reflecting power. A few of the curves obtained are here given. The material used in obtaining the curve shown in Fig. 5 was a polished flake of mother-of-pearl about 0.2 mm. thick. This specimen had a particularly brilliant

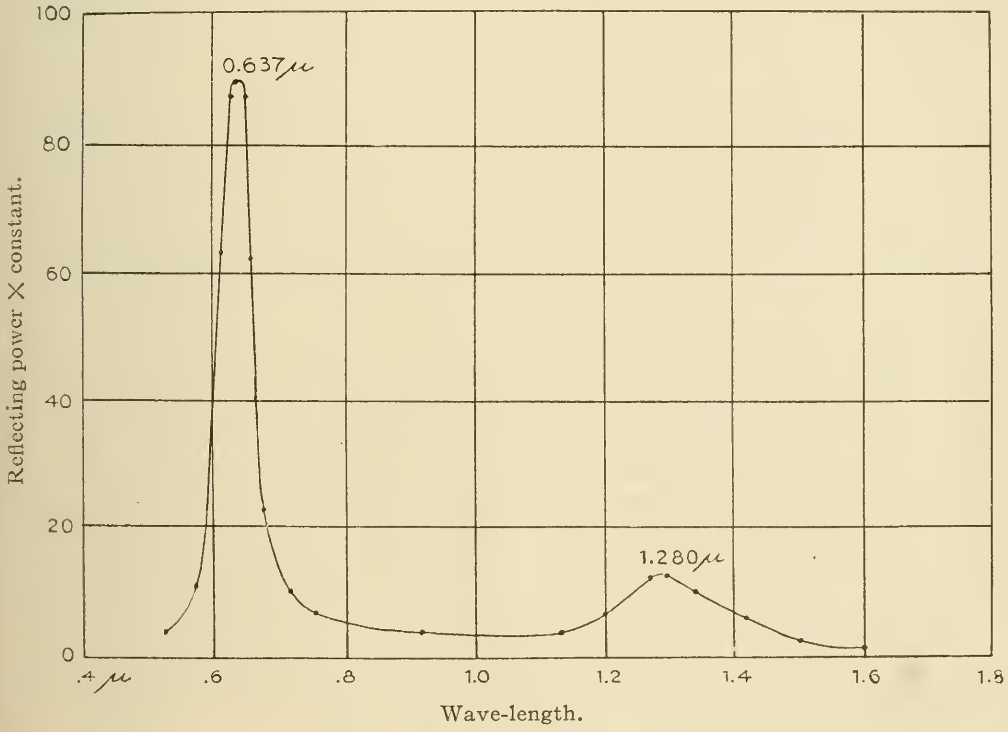
Fig. 4.



spot 1 x 5 mm. in area and from this the light was reflected. The two maxima lie at the wave-lengths 1.28μ and 0.637μ, respectively. Since these wave-lengths are very approximately in the ratio 1 : ½ it is evident that we are dealing with interference maxima of the first and second orders. The sharpness of the maxima indicates a rather remarkable constancy of the thickness of the laminæ.

Practically the same conclusions may be drawn from the curves shown in Figs. 6 and 7. The maxima lie, respectively, at 1.4μ, 0.71μ and 1.86μ, 0.93μ and 0.63μ. As before, the wavelengths of successive maxima bear the ratios 1 : ½ : ⅓ to a very fair degree of approximation—hence the conclusion may be drawn that the iridescent colors of mother-of-pearl owe their existence to interference of light reflected from the parallel and equidistant laminæ.

FIG. 5.



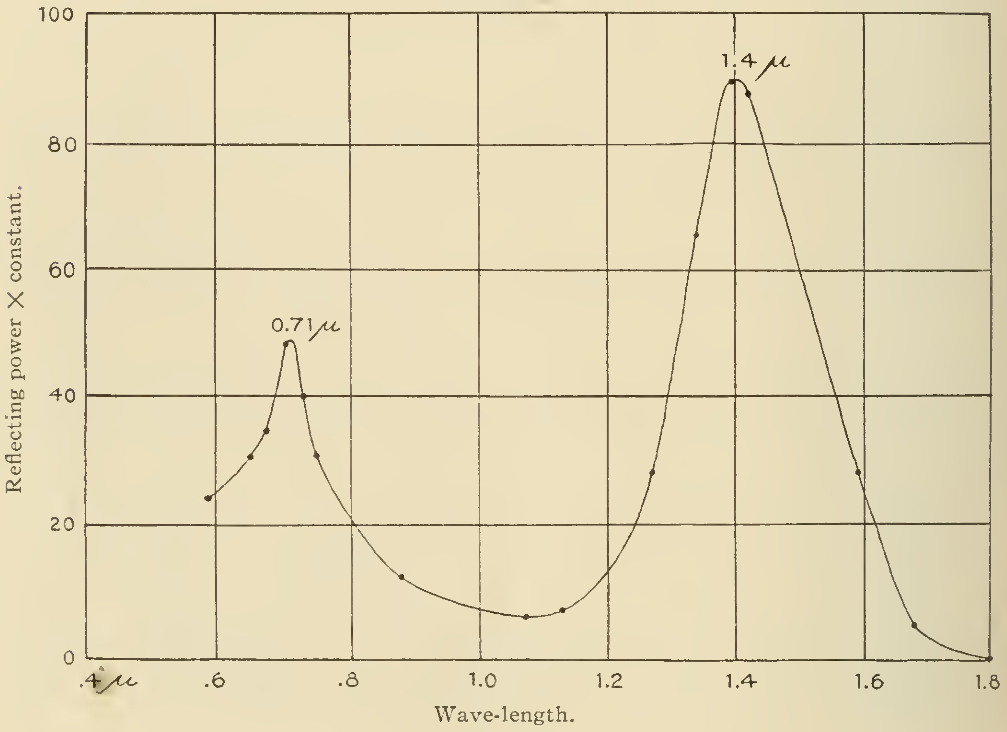
It is obvious, without going into details, that these interference phenomena could best be studied in the infra-red spectrum. Not only is the amount of energy great, but the interference maxima are widely separated and hence may be studied readily. A comparison of the curves in Figs. 5, 6 and 7 reveals a marked difference in the relative intensities of the maxima for one specimen. While a variety of causes may contribute to this effect, the principal ones are:

(1) A difference in the transparency of the nacreous layer to different spectral regions.

(2) Different dispersion curves of the layer of $CaCO_3$ and conchiolin.

Having investigated highly colored shells it seemed of interest to take up the study of nacreous matter which showed no color but a brilliant "pearly" lustre. A suitable region on the inner surface of a Mississippi River mussel shell was found and from this the reflection curve shown in Fig. 8 was obtained. The lack of sharpness of the maxima indicates that the thickness of the laminæ is far from being constant. It is possible to simulate the appearance of such a specimen by heating a piece of mica in a bunsen flame. In consequence of the heating, the mica is split up into numerous laminæ of widely varying thickness.

FIG. 6.



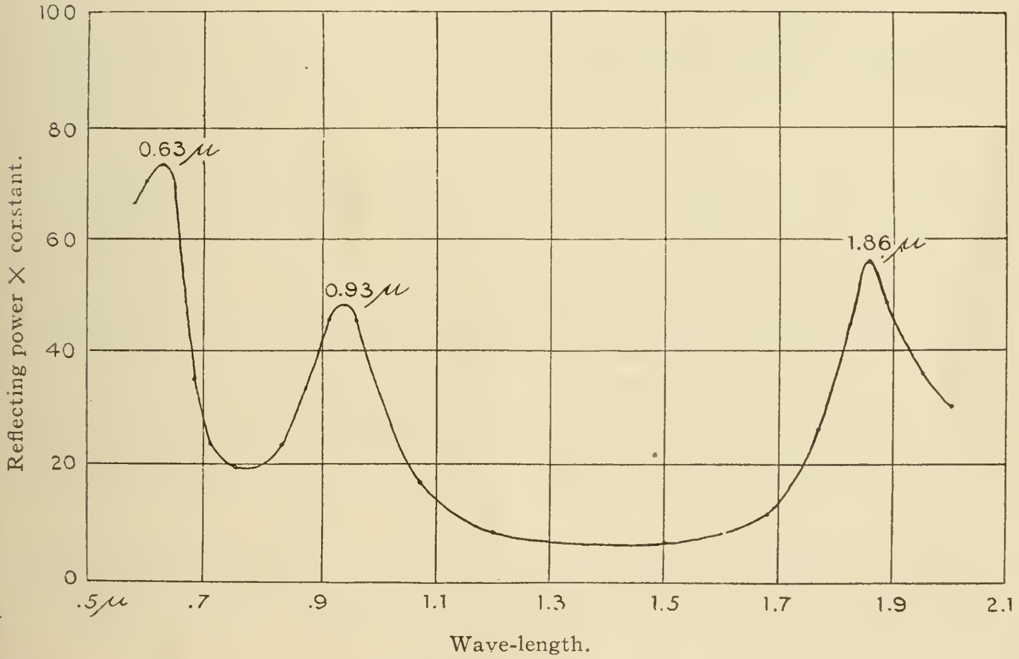
An unsuccessful attempt was made to study, in a similar manner, that area on the outside of the shell which exhibits neither color nor pearly lustre. The character of the chalky material in the shell was such as to scatter the light diffusely—thus preventing regular reflection from successive laminæ. That laminæ exist in this region also is certain, for the diffraction colors seen indicate a spacing of the laminæ which is practically the same as that shown by neighboring iridescent portions.

In order to determine the actual thickness (e) of the laminæ it is only necessary to find the refraction index (μ) and substitute in the expression

$$e = \frac{m\lambda}{2\,\mu \cos\, r}$$

It is, of course, possible to find a fairly transparent portion of a shell and prepare from this an acute-angled prism by means of which μ may be determined. However, it frequently happens that the particular specimen studied is not sufficiently transparent. Then, too, such a determination would only be a grand average which might or might not hold for the small element which was used in the study of the interference maxima. It was soon found that the simplest and most satisfactory method of determining μ was to find the wave-lengths λ_1 and λ_2 at which the first order interference maxima lie when the angles of inci-

FIG. 7.

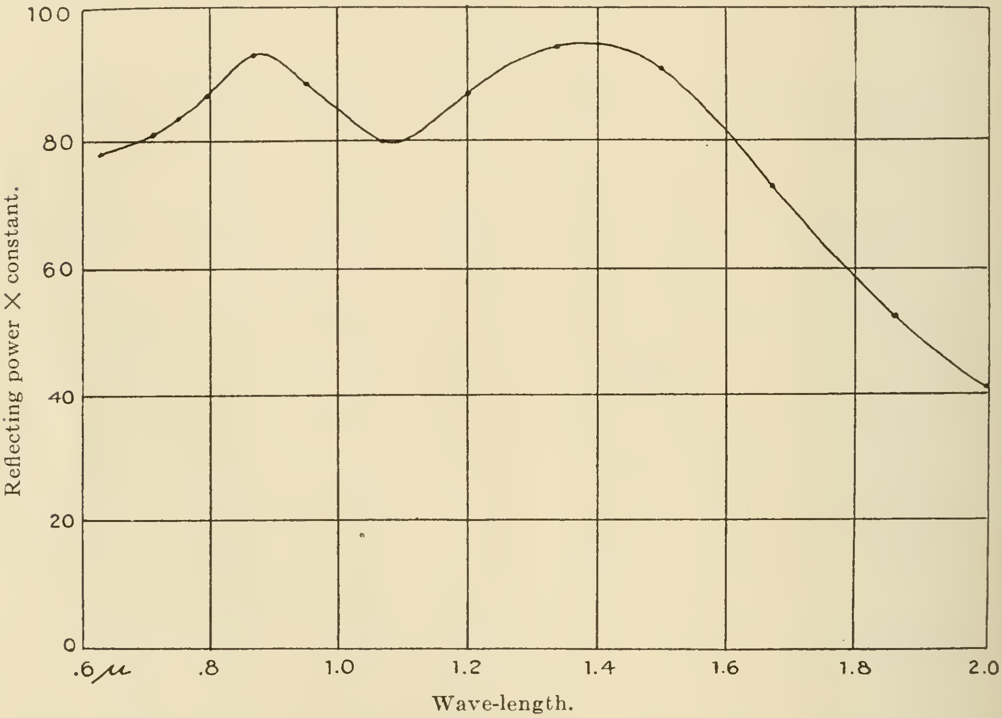


dence are respectively i_1 and i_2. The calculation of μ follows at once from the easily derivable formula:

$$\mu = \sqrt{\frac{\lambda^2_2 \sin^2 i_1 - \lambda_1^2 \sin^2 i_2}{\lambda^2_2 - \lambda_1^2}}$$

The shift of the position of the interference maxima resulting from a change in the angle of incidence is shown in Fig. 9. The specimen studied was taken from an abalone shell. Corresponding to the angles of incidence $i_1 = 11°$ and $i_2 = 50°$ the wave-lengths of the two first order maxima are 1.478μ and 1.288μ. Upon substituting these values in the foregoing formula, the refractive index (μ) found to be equal to 1.54°.[3] This value of the refractive-index when substituted in expression (i) yields the value for the actual thickness of one lamina:

FIG. 8.



$$e = 0.48\mu$$

which is the value of the wave-length of greenish-blue light.—

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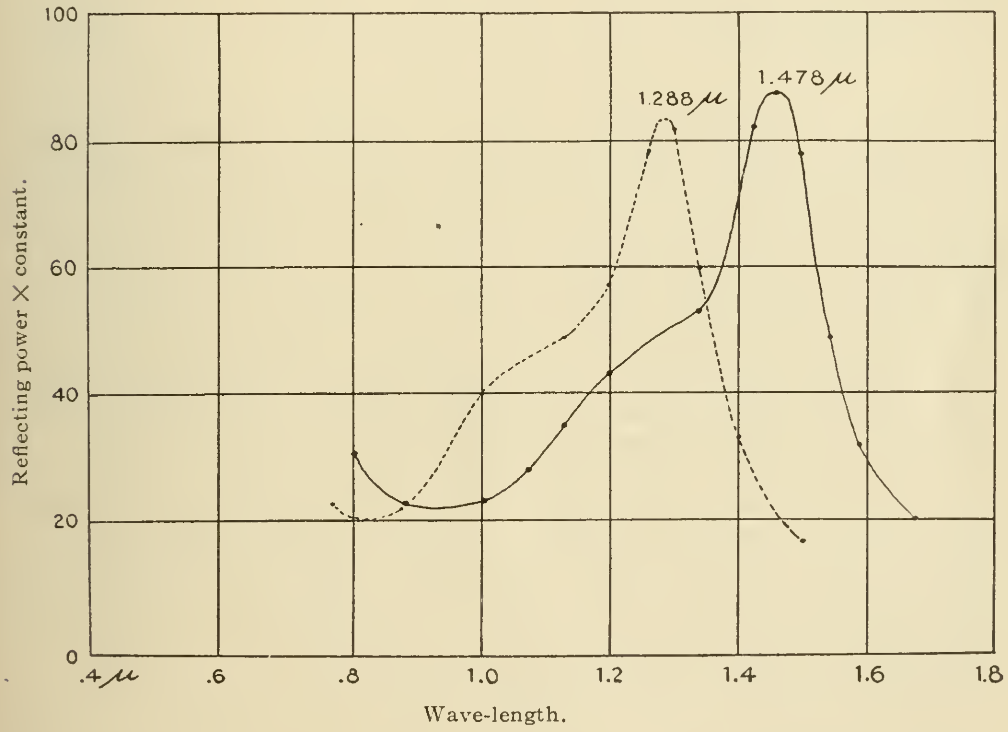
[3] The value of refractive index is practically the mean value for that of the ordinary and extraordinay ray in Iceland-spar ($CaCO_3$) for wave-length 1.45μ. $\mu_o = 1.6361$. $\mu_e = 1.4779$.

Similar determinations of e for other samples of mother-of-pearl all show that the thickness of the lamina is of the order of magnitude 0.4μ to 0.6μ.

Finally, the writer cannot refrain from urging biologists to attack anew the problem of ascertaining the manner in which the layers of nacreous material are deposited. The truly remarkable constancy of thickness of the laminæ demands explanation. That periodic variations in external conditions such as light and darkness, tides, temperature, &c., should be responsible for the deposition of discreet layers seems improbable since the total number of laminæ possessed by a shell of known age is entirely too great to be accounted for on any such hypothesis. Possibly the animal, as such, has nothing to do with the periodicity which gives rise to the laminæ—for, just as the crystals in the minute laminæ exhibited by $KClO_3$ grow only to definite thickness, so may the minute crystals of $CaCO_3$, surrounded by conchiolin, grow only until a certain thickness is reached. These suggestions are merely offered for what they are worth.

FIG. 9.



SUMMARY.

1. Mother-of-pearl owes its colors to two causes:
   - (*a*) Diffraction of light due to a grating-like structure of the terminal edges of successive laminæ.
   - (*b*) Interference of light due to reflection from numerous parallel laminæ of sensibly equal thickness.

2. By means of "replicas" the study of diffraction colors was carried out. Interference measurements were obtained in the infra-red region of the spectrum where conditions are much simplified. From these data the thickness of the laminæ for many different samples was found to lie between the limits 0.4μ and 0.6μ.

JOHNS HOPKINS UNIVERSITY,
January, 1917.

Fuses on Short-circuit. ANON. (*The Electrician* (London), vol. lxxviii, No. 19, p. 568, February 9, 1917.)—It is well recognized that the object of a fuse on an electric circuit is two-fold: Firstly, to prevent overloading of the circuit, and, secondly, to prevent damage to the wiring through short-circuits. On ordinary networks the fuse is called upon mainly to play the part of protector against overloading and against the milder forms of short-circuit; but it is nevertheless realized that every fuse should be capable of taking care of what is termed a "dead short-circuit." The fuse takes a certain time to act—this, in fact, being one of its virtues—but, owing to this characteristic, the current that is carried before actual fusion occurs may be very high under certain conditions, and a state of affairs may be reached in which a small variation in the time constant of the circuit and other factors may make a very considerable difference in the maximum current. This seems to be the explanation of effects observed by Mr. Sydney W. Baynes, the chief electrical engineer of the St. Pancras Borough Council.

Mr. Bayne has found that service fuses have become much less satisfactory in recent years—in fact, since the advent of the steam turbine. The currents that may arise on dead short-circuits through 5-ampère or 10-ampère fuse have now become very heavy, this possibly being partly due to the fact that a momentary overload has a less mechanical effect on a steam turbine than on a reciprocating engine, and partly, no doubt, to the much smaller reactance of the turbo-generator. Experiments show that, owing to the heavy currents that may result, there is a tendency for the arc to flash to any earthed metal in the vicinity of the fuse. Consequently fuses of the cartridge type are favored, and for this reason concrete service boxes have been adopted for all service on the St. Pancras network.

THE ORGANIC NITROGEN COMPOUNDS OF SOILS AND FERTILIZERS.*

BY

ELBERT C. LATHROP, Ph.D.

After establishing the fact that the soil was capable of ammonifying acid amides it was decided to ascertain, if possible, if at any time previous to the first sampling period there occurred a decrease in amide nitrogen and at what time the increase in this form of nitrogen was first observable by the analytical methods. For this purpose some of the original mixture of soil and dried blood which had been shown to have undergone no change during storage, was taken and kept at a ten per cent. moisture content. Samples of this soil were taken at short intervals and analysed for their content of ammonia free in the soil and ammonia in the hydrochloric acid extract after hydrolysis. From these data it was possible to arrive at the amounts of amide nitrogen in the soil at the end of each sampling period. The results so obtained, together with the results already obtained upon amide nitrogen, are presented in Table VIII (p. 466).

The results show that during the second and third days there has been a slight increase in amide nitrogen. This must be considered as being due to the formation of protein material by the microörganisms in the form of their protoplasm, and since there has probably been little hydrolysis of the dried blood proteins at this time, the nitrogen necessary for this synthesis may have been derived from the free amino groups of the lysine of the native proteins of the dried blood, or from the free amino groups of lysine or other amino acids in albumoses which are also possibly present in the dried blood. On the fifth day the amide nitrogen has fallen from 60.15 milligrams at the end of the third day to 8.75 milligrams, a loss of about 70 per cent.

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* Contribution from the Laboratory of Soil Fertility Investigations, communicated by Dr. Oswald Schreiner and published by permission of the Secretary of Agriculture.

Continued from page 321, March issue.

of this form of nitrogen. Since the number of organisms in the soil are constantly increasing, a portion of the amide nitrogen present in the soil at this time must be present in the form of proteins constituting the protoplasm of these organisms. It would appear, therefore, that practically all of the amide nitrogen of the dried blood proteins has been split off in five days, signifying a deep hydrolysis of these proteins.

TABLE VIII.

Amide Nitrogen in the Soil at Various Periods.

Time in days from the beginning of the experiment.	Milligrams of nitrogen per 100 grams of oven-dried soil.	Amide nitrogen expressed in percentages of hydrolysable nitrogen in original soil.
Original soil	57.14	7.008
2 days	59.77	7.329
3 "	60.15	7.363
5 "	8.75	1.606
6 "	34.31	4.207
7 "	38.42	4.628
8 "	60.42	7.408
13 "	57.48	7.020
18 "	61.39	7.515
20 "	60.72	7.110
44 "	49.13	6.025
86 "	44.38	5.429
148 "	28.27	3.454
240 "	26.38	3.222

The amide nitrogen increases from the 5th to the 6th day from 8.75 to 34.31 milligrams; the 7th day shows a further increase, and on the 8th day the amount of amide nitrogen is about that present in the soil at the end of the 3rd day; from the 8th to the 20th day the amount of amide nitrogen, aside from small fluctuations, remains almost constant. This increase must be considered as being due to the synthetic action of the microorganisms in the formation of their protoplasmic proteins. In view of the fact that these proteins, in amount, must be much smaller than the proteins of the dried blood, but that the amide nitrogen content of the soil is even greater than the content of the original soil, it would appear that the proteins formed by the microörganisms must be relatively rich in amide linkages.

The amide nitrogen of the soil, during the time covered from the end of the first period of 18 days to the end of the experiment, 222 days, shows a loss of 57 per cent. This loss is by far smaller than any of the other forms of nitrogen. Since the amide nitrogen was practically all destroyed at the end of the 5th day and then amide nitrogen was synthesized, it would appear that the amide nitrogen built up by the microörganisms exists in proteins which are more resistant to the action of the microörganisms than were the proteins of the dried blood.

The figures in Table VI show that the proportions of amide nitrogen in the soil show an increase up to the 86th day, when 22 per cent. is reached as compared with 7 per cent. in the original soil. The amount then drops off to 19 per cent.

In this connection it is extremely significant that the results obtained by Shorey (1905), Lathrop and Brown (1911), Jodidi (1909, 1911, i, ii), Kelly (1914), Potter and Snyder (1915, i, ii) on hydrolysing the nitrogenous compounds of soils and peats from this country and Hawaii show amounts of amide nitrogen in the soils uniformly higher than are found by acid hydrolysis of animal or vegetable proteins. These figures range between 16 and 30 per cent. of the total hydrolysable nitrogen of the soils. It has further been shown that some of these soils readily ammonify acid amides, indicating that the amide nitrogen exists in protein complexes and not as free acid amides. In the light of the present investigation these various analytical results seem to point to the presence in soils of considerable amounts of microörganismal proteins.

MELANIN AND NON-AMINO NITROGEN.

Owing to the fact that the non-amino nitrogen varies so much throughout the experiment and that the melanins are so little understood, these two forms of nitrogen cannot be profitably discussed.

The results of this investigation are not in strict accord with those recently obtained by Kelly (1915), who studied the decomposition of various sorts of organic matter in Hawaiian soils. He determined the amide, basic, and non-basic nitrogen in casein, dried blood, soy bean cake, cotton-seed meal, linseed meal, cocoanut meal, globulin from cotton seed, and zein from maize, before and after the action of bacteria on these compounds in quartz sand to which a soil infusion had been added previous to incubation. His experiments covered from 3- to 8-day decompositions and the amounts of organic matter used were about one-fourth the amount used in this investigation. He found that, with the exception of linseed meal and zein, the diamino nitrogen was converted into ammonia more rapidly than any other form of nitrogen. In the present investigation the conversion of the diamino nitrogen, arginine, histidine and lysine into ammonia in 240 days amounts to 87 per cent., and the monoamino nitrogen, 89 per cent. The causes for the differences in the results are probably not only the different experimental conditions, but also a difference in the microörganismal flora, producing different types of decomposition.

PROTEINS IN THE SOIL AT THE END OF THE EXPERIMENT.

From the results of the Van Slyke analysis evidence has been found to indicate that there is a formation of protein material taking place in the soil in the course of the decomposition of protein materials, and that perhaps this new protein is somewhat resistant to decomposition. In order to determine whether or not soluble proteins are present in the soil after the decomposition had been proceeding 240 days the portion of the soil which remained was extracted with distilled water for several hours. The solution was then decanted from the soil and filtered. Tests for proteins or protein-like substances in the solution showed that such compounds had not been extracted by distilled water.

The soil was then treated with a 1 per cent. solution of sodium hydroxide for 24 hours and the alkaline solution siphoned off the soil. This solution was acidified with sulfuric acid and was filtered. To this acid filtrate 20 per cent. phosphotungstic acid solution was added until precipitation had ceased, and after allowing the solution to stand for several hours, until the precipitate had settled, the precipitate was filtered off by suction and thoroughly washed with water acidulated with sulfuric acid. The phosphotungstic acid precipitate was suspended in cold distilled water and treated with an excess of barium hydroxide solution in order to free the protein material from the phosphotungstic and sulfuric acids. The excess of barium in the filtrate from the precipitate so formed was removed by carbon dioxide and the barium carbonate was filtered off. The solution was made just acid with dilute sulfuric acid and was boiled for a minute with a little barium carbonate and then filtered. A light straw-colored, turbid solution was obtained, which behaved in general like solutions of protein material. This solution was tested for the presence of proteins or protein-like substances. It gave precipitates with phosphotungstic, phosphomolybdic, tannic, and picric acids, with mercuric chloride, silver nitrate, and copper acetate. The following tests for proteins were positive: Millon's reaction; Biuret test, reddish violet; Spiegler's ring test, weak; Robert's ring test, weak; Hopkins-Cole reaction; and Liebermann's reaction. Acetic acid and potassium ferrocyanide solution, when added to the soil extract, did not produce a precipitate, but a precipitate was formed when a solution of sodium chloride containing acetic acid was added. The protein material could be salted out by solid sodium chloride, and by ammonium sulfate. A precipitate was formed on the addition of sufficient alcohol to make a 50 per cent. alcoholic solution, and the filtrate from this precipitate when treated with a large amount of absolute alcohol formed a further precipitate. A distinct cloudiness was formed in the solution on the addition of a half saturated solution of ammonium sulfate. By these reactions the presence of proteins or protein-like substances in the soil is established. The exact class to which this protein material belongs could not be determined excepting by a more extended investigation, and this point was not of particular interest. This established the fact that after a 240-day decomposition of dried blood in the soil, proteins, or protein-like complexes, not extractable by distilled water but soluble in dilute alkaline solution, are present in the soil. Whether they are proteins from the bodies of microörganisms in the soil, or whether they are residues from the dried blood which have until this time resisted decomposition by the microörganisms of the soil cannot be stated.

Of interest in this connection is the fact that Walters (1915) has recently reported the isolation from a field soil of protein-like complexes which gave reactions for proteoses and peptones, bodies similar in nature and reaction to the compound here reported.

No attempt was made to isolate free amino acids from the soil after the decomposition period, since the quantities of soil were too small.

EFFECTS OF NITROGENOUS DECOMPOSITION PRODUCTS OF PROTEINS ON THE GROWTH OF THE HIGHER PLANTS.

Proteins and nucleoproteins have long been known to be essential constituents of plant and animal cells. The nitrogenous compounds thus far isolated from soils are for the most part primary protein decomposition products. These compounds may be present in the plant cell in the form of nucleoproteins and other proteins, and in addition it has been shown that these decomposition products of proteins may also occur in the plant tissues as such; for example, xanthine, creatinine, arginine, guanine, etc. These compounds which are so essential to growth must either be synthesized by the plant or they must be acquired in some other manner, such as absorption from the media in which they grow. It becomes of interest, therefore, to observe what effects these decomposition products, known to occur in soils, have upon plants.

There has long been a popular conception that the nitrogen metabolism of plants and animals was fundamentally different. This conception has arisen from the demonstration of two facts; plants are able to build up their protein materials with nitrates and ammonium salts as a source of nitrogen; animals, on the other hand, cannot build up protein from such nutrients as a source of nitrogen but require for their building the already complex organic nitrogen compounds. Recent investigations have demonstrated the unsoundness of this conception, for it has been shown that, although animals cannot utilize the simple nitrogenous compounds, the plant is not confined to these but may also use the more complex nitrogen compounds in their growth.

The building up of protein material by the plant from the nitrate and ammonium salts is a complex chemical transformation which is certainly not completed in one step. While our knowledge of this transformation is experimentally rather uncertain, still, from the fact that many of the simpler compounds which compose the proteins are known regularly to occur in plants, it seems altogether probable that these compounds, the amino acids, purine bases, etc., are first synthesized by the plant and then are linked together to form the still more complex nitrogenous compounds. If, then, the plant is able to absorb these protein decomposition products directly and utilize them in the building up of its proteins, it is obvious that a large expenditure of energy is saved the plant. In addition, in considering the energy efficiency of metabolism, it becomes apparent that the plant must expend a considerable amount of energy in transforming nitrate nitrogen (NO_3), a highly oxidized nitrogen form, into the amino groups (NH_2) and imino groups (NH), highly reduced forms, in which the nitrogen in amino acids, purine bases, creatinine, etc., is found. If this expenditure of energy is saved the plant by utilizing the building bricks at hand, such as the amino acids, purine bases, etc., in its metabolism, instead of first manufacturing them, it becomes evident that the energy so saved may be used by the plant in other metabolic processes, thus augmenting growth.

The effects of these compounds isolated from soils, together with many other decomposition products of protein material, have been studied, chiefly by Schreiner and his colleagues Reed (1907) and Skinner (1911, 1912), and also by other investigators, notably Hutchinson and Miller (1911). These investigations have shown that many of the compounds are of themselves beneficial to the growth of the plant in water culture solution and that they are apparently absorbed by the plant as such, without first being transformed into ammonia and nitrates. Among the compounds tested are nucleic acid, hypoxanthine, guanine, histidine, arginine, and creatinine. All of these compounds were shown to be decidedly beneficial to the growth of wheat seedlings. Take, for instance, hypoxanthine. The effect of this soil constituent was studied in solutions containing many different ratios of fertilizer elements. The effect of the hypoxanthine was very marked in those cultures containing phosphate and potash, but no nitrate. The average increase in growth in these cultures was 41 per cent., due to the presence of 100 parts per million of hypoxanthine. When nitrate was also present the increase due to hypoxanthine was not so great, but it was shown that in the presence of hypoxanthine less nitrate was consumed by the plants. All other compounds mentioned above behave in the same general way.

In the absence of nitrate, nucleic acid gave an increase of 74 per cent., histidine gave an increase of 30 per cent., arginine an increase of 33 per cent., creatinine an increase of 36 per cent.

In addition to showing that many of these compounds are directly absorbed by the plants, and that they may act as nitrate sparers, less nitrate being used by the plants in their presence, Schreiner and Skinner (1912) have shown that these compounds collectively are more beneficial than when used singly. For example, they found that taken singly, histidine, creatinine, and asparagine were each beneficial nitrogeneous compounds, causing an increased growth of wheat seedlings, but that when the three compounds were present together in the same solution that the growth was greater than it had been in the presence of any single one of the three. From this they argue that the differences in the action of these compounds are due to an inherent property of the compounds themselves, which make it impossible for one wholly to replace the other in plant metabolism.

It must not be supposed, however, that all nitrogenous compounds are beneficial to plant growth. Guanidine is an especially fine example of this fact. This compound, which has not yet been found in soils, but which, as has been mentioned, may be formed by the action of microörganism on guanine, or arginine, and possibly also creatinine, is decidedly harmful to plant growth. It is toxic to wheat seedlings in the low concentration of 25 parts per million. The action of the compound is manifested on the tops of the plant, causing effects entirely similar to a wilt disease. It is interesting to observe that the presence of nitrates increases remarkably the toxic effects of guanidine, whereas nitrates are usually beneficial.

Several points established by these investigators are of tremendous importance to practical as well as theoretical agriculture. They have shown that not only nitrates and ammonia may serve as the source of nitrogen for the higher plants, but that most of the decomposition products of proteins and nucleoproteins may also be utilized by the plant. These compounds are apparently absorbed unchanged and a combination of them is shown to have a more beneficial action on plant growth than is produced by the compounds singly. They cannot only increase growth in the absence of nitrates, but when nitrates are also present less nitrate is consumed by the plant. Not all nitrogenous decomposition products of proteins are beneficial, some of them being decidedly harmful. Thus not only the nature of the nitrogenous compounds present in the soil is of importance to plant economy, but the diversity of the compounds is equally important. The knowledge thus gained introduces the possibility of interpreting on rational grounds the action and availability of nitrogenous fertilizers, and other nitrogenous organic matter when introduced into the soil, and shows clearly the necessity of a more intimate chemical knowledge of this sort of material.

EFFECTS OF NITROGENOUS DECOMPOSITION PRODUCTS OF PROTEINS ON THE GROWTH OF MICROÖRGANISMS.

In considering the relation of the nitrogenous constituents found in soils to the problems of soil fertility it is necessary not only to know what the effects of these compounds on the higher plants may be, but the effects which they may have on the growth of the microörganisms in the soil must also be established. It is well known that the general metabolism of the autotrophic and the heterotrophic plants is different and it might be expected *a priori* that the effects of the nitrogen compounds on these two classes of plants would also be different. The microörganisms which grow in the soil seem to be more specialized in their functions than are the higher plants and are more sensitive to the media in which they grow, requiring in many cases rather special conditions. A large number of investigations have been conducted which have more or less bearing on this subject, and it seems that they warrant a brief discussion.

From the standpoint of nitrogen metabolism microörganisms have been divided by Beijerinck (1890, 1901) and Jost (1900) into several fairly distinct classes: (1) *Nitrate organisms,* which seem to thrive as well, if not better, in the presence of nitrates as the sole source of their nitrogen, than if other compounds are also present. (2) *Ammonia organisms,* which seem to prefer ammonia or ammonium salts to other forms of nitrogen as a source of nutrient. (3) *Amide organisms,* which seem to do better in the presence of amides, amino acids, etc., than with either nitrates or ammonia. (4) *Peptone organisms,* which seem to require peptones, the compounds formed among the first products of protein hydrolysis. Amino acids, amides and proteins do not seem to serve as a source of nitrogen for these organisms. (5) *Protein organisms,* which require only proteins as a source of nitrogen. These organisms are known to exist in nature only as parasites. Some organisms can grow on several kinds of media and others are inhibited or cannot grow at all in the presence of one kind or another of nitrogen compounds.

For our knowledge of the various sources of nitrogen which may be used by bacteria we are indebted to the investigations of Bierema (1909), Nawiasky (1908, i, ii), Ellinger (1898, 1899, 1900, 1903), Hoppe-Seyler (1876, 1877, 1878), Baumann (1879, 1880, i, ii, 1883), Sasaki (1912, i, ii), Borchardt (1909), and many other prominent investigators. It is, however, due particularly to Bierema and Nawiasky that we know that bacteria can utilize a wide range of substances for their source of nitrogen. Among the substances which have been tested are aspartic acid, glutamic acid, leucine, phenylalanine, tyrosine, arginine, and many other amino acids, peptones, albumoses, polypeptides, proteins, urea, uric acid, guanidine, creatinine, ammonium salts, both of organic and inorganic acids, acid amides, such as asparagine, etc.

Czapek (1902, i, ii, iii), Emmerling (1902), Butkewitsch (1903), Brenner (1914), Zaleski (1914), and Kossowicz (1912, 1913, i, ii, 1914) have quite thoroughly studied the metabolism of molds. Emmerling showed that molds utilize quite readily the α-amino and λ-amino acids but seem to be unable to utilize the β-amino acids. Czapek studied the growth *Aspergillus niger* on a vast number of nitrogenous compounds, which included amines, diamines, acid amides, nitriles, ureids, purines, nitro-derivatives, hydrazines, oximes, cyclic amines, cyanides, and sulfocyanides, amino acids, etc. The mold could not utilize all of these compounds but grew well on a very large number. Kossowicz has shown that molds can utilize urea, uric acid, glycocoll, guanidine, guanine, nitrates, nitrites, and ammonium salts as a source of their nitrogen, and that uric acid, glycocoll and hippuric acid may serve as a source of carbon as well.

Due to the researches particularly of Ehrlich and Neuberg, we have an understanding of the nitrogen metabolism of yeasts. It has been shown, for example, that yeasts may derive the nitrogen for their growth from a single amino acid. They seem to be able to utilize quite well most, if not all, of the amino acids. In so doing they apparently desaminize the amino acid and use in their metabolism only the ammonia formed.

An important class of soil organisms which has not been mentioned is that which utilizes the nitrogen of the air. Reed and Williams (1915) have recently made a study of the effects of certain of the compounds found in soils, together with others which may occur there, upon the nitrogen fixation of one of these organisms, *Azotobacter.* They report that such compounds as nicotine, picoline, guanidine, and skatol exhibit toxic properties commensurate with those usually ascribed to these substances. Caffeine seems to have a stimulating effect. Many of the nitrogen compounds which are beneficial to plants they found to exercise a marked depression on nitrogen fixation. The simple compounds seemed to be more pronounced in this respect than the more complex. Urea, glycocoll, formamide, and allantoin were especially active in depressing fixation.

In regard to the action of guanidine, a compound toxic to the higher plants, the reports are conflicting. Bierema reports that molds and bacteria ammonify it only very slowly, Shibata reports that *Aspergillus niger* has no effect on it. Czapek and also Kossowicz report that it may be used as a source of nutrient. Reed and Williams report that it is toxic to *Azotobacter.* The reason for this divergence is doubtless due to the difference in the conditions of the media and the organisms studied.

From this brief sketch of the action of these compounds on the growth of the microscopic plants in the soil it becomes apparent that, as is the case with the higher plants, each compound is of significance from the standpoint of plant physiology and plant economy. The appearance in the soil at any time of a compound in sufficient concentration may mean that the normal growth of the higher plants, or the lower plants, or both, will be hindered. The appearance of other compounds may mean that the growth of the plant will be greatly stimulated and hastened. It is probable that all times there exist in the soil, compounds which are beneficial and compounds which are harmful, not only to the higher plants growing on the soil, but also to the organisms which inhabit it. The depression or stimulation of one type of organisms in their growth will, in turn, affect the growth of the higher plants and of other types of organisms.

Thus we see that the whole process is very complex, that it is constantly in a dynamic condition and that the net result of all this will be fertility or infertility, depending on which set of factors predominates in the soil at any one time. Just as it is possible to control the course and direction of a fermentation process, certain end products being obtained, so should it be possible to control these conditions which affect the fertility of the soil, but it is necessary to know in this case, as in the case of the fermentation process, just what the compounds are which react, and the effects which they have on each other and on the other factors of the soil.

THE CHEMISTRY OF THE NITROGEN OF ORGANIC FERTILIZERS.

Of the three so-called essential elements for plant growth nitrogen is the one which does not occur plentifully in the earth's crust, with few notable exceptions. It must, therefore, be supplied to the soil if fertility is to be maintained. Nitrogen seems to have the quickest and most pronounced effects of the three essential elements and tends to promote the above-ground growth of the plant. It has been stated that one of the possible limiting factors to crop production is the lack of water-soluble nitrogen compounds at critical periods in amounts necessary for the normal development of the crop. The nitrate and ammonium salts are extremely soluble in water and are quickly leached out of the soil. Organic fertilizers, on the other hand, seem to have a more lasting, although not so immediate, effect. Many crops, especially truck crops, are successfully grown when supplied with organic nitrogenous fertilizing materials.

The chemical nature of the nitrogen of the inorganic or mineral fertilizers is quite simple and the changes which they undergo in the soil are considered to be well understood. Unfortunately, the same cannot be said of the organic nitrogenous fertilizers, for we do not know, except in a very general way, much concerning the forms in which the nitrogen exists in these diversified products, and the manner in which they decay in the soil has just begun to be studied from the chemical and biochemical viewpoint.

NATURAL ORGANIC FERTILIZERS.

The organic nitrogenous fertilizers may be divided generally into two classes: Natural organic fertilizers and Processed organic fertilizers. To the first class belong the organic trade wastes and municipal refuse which are of such a character that they may be used for fertilizer purposes without further treatment. To the second class belong the wastes which in order to be used as fertilizers must first undergo some sort of chemical change.

The nitrogen of the fertilizers of the first class exists largely in the form of complex organic compounds, generally in proteins or nucleoproteins which decompose rather easily and quickly in the soil. Dried blood is one of the best representatives of this class of fertilizers. It has been shown in another section of this paper that it is composed of protein materials, and the results of the Van Slyke analysis for the various forms of nitrogen have already been presented. Further, it has been shown that this fertilizer is quickly hydrolysed in the soil and eventually largely ammonified.

Analyses by the Van Slyke method have recently been made of certain other fertilizing materials which belong to this class; for example, cotton-seed meal and tankage. The results of these analyses made by Nollau (1915) and by Grindley and Slater (1915) are presented in Table IX.

TABLE IX.

Analyses of Certain Organic Nitrogenous Fertilizing Materials According to the Van Slyke Method.

	Nollau (1915)		Grindley and Slater (1915)		
Form of nitrogen	Swift's digestor tankage	Cotton seed meal	Cotton seed meal	Tankage	Blood meal
Ammonia nitrogen	10.03	14.06	10.45	6.58	5.85
Melanin nitrogen	6.88	6.27	7.78	4.40	3.95
Cystine nitrogen	2.46	2.74	0.65	1.28	0.69
Arginine nitrogen	12.34	12.77	19.52	14.15	9.16
Histidine nitrogen	2.18	7.57	5.47	4.94	8.53
Lysine nitrogen	2.50	1.94	4.78	7.48	9.73
Monoamino nitrogen	54.73	45.02	42.82	52.39	56.57
Non-amino nitrogen	9.10	7.49	5.34	7.27	4.42

A comparison of these results with those obtained on dried blood shows much similarity in the composition of all of these materials, and it might be expected that their decay in the soil would proceed much as the decay of the dried blood.

THE NITROGEN OF PROCESSED FERTILIZERS.

On the market are a very large number of fertilizers which may be characterized as "processed," *i.e.,* the crude materials, not in themselves permissible as fertilizers, are made to undergo some decided chemical change in order to render them suitable as plant nutrients. It has been found that the availability of the crude substances is nearly always greatly increased by such processing and that a much larger percentage of the nitrogen in the finished product is soluble in water, although the actual chemical changes produced seem to have received little attention. The chemical compounds in processed fertilizers which are here shown to have direct fertilizer significance have not previously been determined, other than to show that ammonia was formed during the processing and that ammonia is more readily produced from the processed goods.

Since the wastes from which this type of fertilizer is made contain more or less protein, or protein-like substances, it seemed quite obvious that the finished fertilizer must contain more or less of the chemical compounds which would arise from pure proteins by similar treatment in the laboratory. As the action of many of this class of compounds on plants has been determined, it is evident that the finding of such compounds in the fertilizers would throw much light on the question of the availability of the nitrogen in the fertilizer itself.

BASE GOODS A TYPE OF PROCESSED FERTILIZER.

For a chemical study of processed fertilizers a sample of "wet mixed" or "base goods" fertilizer was chosen as a representative of this type of fertilizer material. The base goods was obtained directly from the factory for use in this investigation. This fertilizer is made by the treatment of various trade wastes and refuse, such as hair, tankage, leather scraps, etc., with rock phosphate and the required amount of sulfuric acid. The materials are mixed together in a "den" and the resulting mass is allowed to stand for several days, or until it is cool enough to be conveniently handled. In the course of the reaction the mass reaches a temperature approximating 100° C., and the identities of the original substances are almost or entirely lost Under these conditions it is certain that more or less hydrolysis of the proteins in the crude materials takes place, with the formation of proteoses, peptones, polypeptides or the simple amino acids, the kinds and number of the products necessarily depending on the proportion of the different proteins in the original materials, on the amount and strength of the acid, the length of time of the reaction, and the temperature reached during the treatment.

Hartwell and Pember (1912) have made a study of base goods in order to determine the availability of the nitrogen contained compared with that of the high grade fertilizers. The product they used was made from hair tankage, garbage tankage, and roasted leather, together with rock phosphate and sulfuric acid. Tables X and XI give their figures for the analysis of the crude materials used in producing the fertilizer and of the finished product.

TABLE X.

Percentages Total Nitrogen in Crude Materials and Finished Product.

(Hartwell and Pember.)

Hair tankage	6.28
Roasted leather	6.49
Garbage tankage	2.87
Base goods including the above	1.68
Water soluble nitrogen in base goods	1.28
Water insoluble nitrogen in base goods	0.40

TABLE XI.

Percentages of Total Nitrogen Present in Different Forms.

(Hartwell and Pember.)

	Before put into den	After removing from den.
In ammonia	6.5	14.3
In water-soluble organic matter	7.8	57.7
In water-insoluble organic matter	85.7	28.0

The experimental work in this investigation was along two separate lines:

(1) Analytical, involving total nitrogen determinations and the separate estimation of the various forms in which the nitrogen may occur.

(2) A determination of the definite chemical compounds present in the fertilizer by suitable methods of isolation and identification.

For the analytical study of the forms of nitrogen in the fertilizer the method of Van Slyke was used in its essential details, excepting that cystine was not determined. The analytical figures obtained by this method appear in Table XIII and will be discussed after the isolation of certain of the constituents has been presented.

The methods used for isolating and identifying the various organic compounds are such as have been used for separating these compounds from soils and have already been presented.

Since this investigation aims only at an explanation and exposition of the general chemical principles involved in the treatment of trade wastes and other organic material to render the nitrogen contained therein more available for agricultural purposes, it does not aim to present the research methods here employed as general methods for analysing such fertilizers. Nor can the quantitative relationships obtained be expected to apply to all products of similar manufacture, for the reason that the different kinds of nitrogen compounds will necessarily show different proportions according to the nature of the materials which enter into the mixture.

The compounds which were isolated from the base goods are tabulated in Table XII according to the sources from which they have been derived and the chemical groups to which they belong.

TABLE XII.

Organic Nitrogenous Compounds Isolated from Sample of Base Goods.

Arginine	Diamo acids or hexone bases	Products of protein hydrolysis by acid treatment of raw materials.
Histidine		
Lysine		
Leucine	Monoamino acids	
Tryosine		
Guanine	Purine base	Plant constituent or product of hydrolysis of nucleoprotein.
Hypoxanthine	Purine base	Plant constituent, or product of conversion of nucleoprotein base.

THE EXPERIMENTAL RESULTS.

Establishing the presence of these products of acid hydrolysis of proteins, namely, the diamino acids, arginine, histidine, and lysine, and the two monoamino acids, leucine and tyrosine, in the amounts in which they were found is of itself of sufficient evidence to demonstrate that by the acid treatment of the crude materials used in the manufacture of the base goods, the proteins contained therein have been changed. This change is shown to be a deep-seated one, since five of the compounds known to be final products of protein hydrolysis by acids are found. This cannot, however, be taken to mean that the proteins have been completely hydrolysed by the acid treatment, since it is possible to have present in the products of partial protein hydrolysis, not only the diamino and monoamino acids but also such intermediate compounds as polypeptides, peptones, proteoses, etc.

In this connection the results obtained by use of the Van Slyke method, and given in Table XIII, are of particular interest. For the nitrogen partition two samples of base goods were extracted: (1) with boiling water, and (2) with boiling acid. In the former case only slight further hydrolysis of the materials in the base goods is to be expected, since the free acid in the fertilizer is extremely weak, and the boiling temperature, 100° C., is that reached in the process of manufacture. In the case of the second extract complete, or practically complete, hydrolysis of all of the protein or protein-like materials is to be expected, since in addition to the original hydrolysis the material was boiled with strong hydrochloric acid for 24 hours, a treatment sufficient for the hydrolysis of most proteins. The differences in the results obtained from the analysis of the two extracts may, therefore, be expected to throw some light on the question of the completeness of hydrolysis of the original proteins by the acid processing.

Without discussing the significance of all of these figures obtained by the use of this method it is interesting to note that the differences between the water extract and the hydrochloric acid extract indicate the presence in the base goods of a nitrogenous compound not yet completely hydrolysed.

In order to prove the presence of some intermediate product of protein hydrolysis, which is thus indicated by analytical methods, an aqueous solution of about 2.5 pounds of base goods was made and the diamino acid fraction was precipitated with phosphotungstic acid in the presence of 5 per cent. sulfuric acid. The precipitate which formed was allowed to stand over night and after filtering it was washed thoroughly with 5 per cent. sulfuric acid and dissolved in sodium hydroxide. The phosphotungstic acid was then precipitated by adding barium hydroxide solution, and after filtering, the excess of barium was removed by adding sulfuric acid until a neutral reaction was obtained. Portions of this solution were tested for peptones, proteoses, etc., with the following results: (1) The biuret test was positive: (2) a precipitate was obtained on saturation of the solution with ammonium sulfate, or with sodium chloride; (3) when the filtrate from the latter solution was treated with acetic acid a cloudy precipitate developed; (4) precipitates were also obtained with sulfuric acid, hydrochloric acid, phosphomolybdic acid and with phosphotungstic acid; (5) a precipitate was formed on the addition of alcohol to the solution. This precipitate was filtered off, dissolved in dilute alkali, and on addition of a very dilute copper sulfate solution the biuret reaction was again obtained. These reactions are those which are given by proteoses and by the proteins and confirm the conclusions arrived at from the results with the Van Slyke method. The Millon reaction and the Hopkins-Cole reaction were both negative, showing the absence from this protein-like material of the tyrosine and tryptophane radicals.

TABLE XIII.

Nitrogen Forms as Determined by the Van Slyke Method.

Form of nitrogen	Results expressed in per cent. of			
	Base goods		Total N in base goods	
	Extract		Extract	
	H_2O	HCl	H_2O	HCl
Total nitrogen	1.610	1.610	....	....
Total soluble N	1.372	1.435	85.24	88.64
Total insoluble N	0.238	0.175	14.76	11.36
Amide N	0.374	0.382	23.23	23.70
Melanin N	0.031	0.074	1.95	4.61
Arginine N	0.111	0.104	6.89	6.46
Histidine N	0.117	0.070	7.26	4.38
Lysine N	0.081	0.117	5.06	7.26
Monoamino acid N	0.543	0.546	33.75	33.92
Non-amino N	0.114	0.133	7.10	8.27

A very large number of compounds intermediate between the protein and its primary hydrolysis products may occur, depending on a great variety of conditions, so that the actual identification of the compounds under discussion would be a difficult matter. However, the nature of this compound may be approximately determined by the results obtained in the study of the two extracts by the Van Slyke method. These results indicate the presence in the base goods of a compound of a proteose nature, which, since it gives a biuret test, must be composed of at least three amino acids. The results indicate still further that the compound is composed of acid amide radicals, diamino acids—particularly lysine—and monoamino acids, those containing amino nitrogen, and especially those containing non-amino nitrogen. Since the figures obtained by the nitrogen partition method are subject to a certain amount of error when applied to such a mixture, the figures can be taken as only approximate for the various forms of nitrogen which make up this compound.

In Table XIV are given the primary hydrolysis products of a number of proteins which may be present in the base goods. These results were obtained by the esterification method and show how the different proteins vary in the nature and amounts of the units composing them. Many monoamino acids, besides leucine and tyrosine, occur in these proteins, and there must consequently be present in the base goods amino acids other than the two isolated. This is apparent from the composition of the various proteins shown in the table. Owing to the large amounts of amide nitrogen in the fertilizer, which was split off by the acidulation of the original proteins of the trade wastes, it may be concluded that considerable quantities of aspartic and glutamic acids are present in this sample of base goods.

TABLE XIV.

Products of Acid Hydrolysis of Various Proteins.

Compound	"Synotin" from cattle (1)	Keratin from sheep's horn (2)	sheep's wool (2)	horse's hair (3)	Halibut muscle (4)	Ox muscle (5)	Legumin from peas (6)
Glycocoll (a)	0.5	0.5	0.6	4.7	0.0	2.1	0.4
Alanine (a)	4.0	1.6	4.4	1.5	(?)	3.7	2.1
Valine	0.9	4.5	2.8	0.9	0.8	0.8	...
Leucine (a)	7.8	15.3	11.5	7.1	10.4	11.7	8.0
Phenylalanine (a)	2.5	1.9	....	0.0	3.1	3.2	3.8
Tyrosine (a)	2.2	3.6	2.9	3.2	2.4	2.2	1.6
Serine	...	1.1	0.1	0.6	(?)	(?)	0.5
Cystine (a)	...	7.5	7.3	8.0	...	...	...
Proline	3.3	3.7	4.4	3.4	3.2	5.8	3.2
Aspartic acid (a)	0.5	2.5	2.3	0.3	2.8	4.5	5.3
Glutamic acid (a)	13.6	17.2	12.9	3.7	10.1	15.5	17.0
Tryptophane	...	...	...	...	+	+	+
Arginine (a)	5.1	2.7	...	4.5	6.4	7.5	11.7
Histidine (a)	2.7	...	...	0.6	2.6	1.8	1.7
Lysine (a)	3.3	0.2	...	1.1	7.5	7.6	5.0
Ammonia (a)	0.9	...	...	...	1.4	1.1	2.1

(1) Abderhalden and Sasaki (1907)
(2) Abderhalden and Voitinovici (1907)
(3) Abderhalden and Wells (1905); Agiris (1905)
(4) Osborne and Heyl (1908)
(5) Osborne and Jones (1909)
(6) Osborne and Heyl (1908)
(a) Physiological action on plant growth has been determined.

The conclusion to be drawn from the results obtained by the examination of this fertilizer by means of the analytical and isolation methods is as follows: The process by which the nitrogen of certain trade wastes, such as hair, leather, garbage, etc., is made more available is recognized as a process of partial hydrolysis of the complex proteins contained in such materials, resulting in ammonia, amino acids, etc., all of which are more readily available than the original protein materials; this hydrolysis is almost complete, the nitrogenous compounds formed being principally the primary products of protein hydrolysis, together with a small amount of proteose-like compound which has not been fully decomposed.

THE AVAILABILITY OF THE NITROGEN OF ORGANIC FERTILIZERS.

The question of the agricultural value of organic fertilizers is one of vital importance to the farmer and to the producer as well. The exploitation of agricultural fertilizers of little or no agricultural value and their use in mixed fertilizers has been a contributing factor for the necessity for state laws and rigid chemical inspection by the state regarding the labeling and sale of such goods. And not until the chemical nature of these products and their biochemical changes in the soil in relation to their effects on plant growth are thoroughly understood will this matter be placed upon a strictly equitable basis.

The determination of the agricultural value or availability of organic nitrogen fertilizers is a knotty problem and one which has received extended study. Numerous methods have been proposed for the determination of this factor, and while many of them give helpful results and have received trade recognition, all of the strictly chemical methods are open to objection. This is due to the fact that the chemical nature of the nitrogenous substances under examination is not known or only guessed, account being taken only of the ammonia formed by the chemical treatment involved and the consideration of the intermediate products of decomposition being neglected. The methods are consequently empirical and the application of empirical methods to the analysis of unknown heterogeneous substances is not apt to lead to a real solution.

The nature of the decomposition products of organic fertilizers in the soil is but partly understood. Ammonification and nitrification have received much attention, but the intermediate decomposition products have not been investigated to such an extent, and the action of these in affecting plant growth has but recently been receiving proper attention. It has been shown that a large number of nitrogen compounds, especially the decomposition products of proteins or nucleoproteins, are physiological factors in plant growth, and their appearance either in the fertilizer or their appearance in the soil as decomposition products of the fertilizer therefore becomes of economic importance.

Of the fertilizers which are composed most largely of protein material, such as dried blood, cotton seed meal, fish scrap, and feathers, some are classed as being high-grade and some as low-grade. The distinction between these different grades of protein materials is that some of them decay very rapidly in the soil, while others decay only very slowly or not at all. In other words, from the biochemical viewpoint the more available ones are easily hydrolysable and the less available are hydrolysed only with extreme difficulty. In order to be used by the plant the nitrogenous material must be in a soluble form and apparently in a form simpler in structure than the protein itself.

In considering the availability of the nitrogen of organic fertilizers it is evident from the discussion which has preceded that a determination of the amount of nitrogen in the form of nitrate or ammonium salts in the fertilizer will not give an adequate idea of its agricultural value. It is equally obvious that a simple determination of the amount of ammonia formed by means of various chemical treatments will not solve this question, since such a determination will not indicate the amount of the intermediate compounds formed by the decay of the organic matter of the fertilizer in the soil, nor will it show their character or their action on plant growth. It is certain that a very large number of nitrogenous compounds in the soil besides nitrates and ammonium salts are of direct importance to plant growth. The question of the availability of nitrogen compounds can therefore only be answered when the nitrogen compounds contained in the fertilizer can be determined in amount and at the same time classified according to their physiological action on plant growth. It is hardly necessary to state that such a method does not exist at the present time and that the physiological action of only a part of the nitrogenous compounds present in the fertilizer is known.

However, from the results obtained from the chemical study of base goods, which has just been reported, it is possible to draw certain conclusions as to the availability of this fertilizer. Both of the purine bases isolated from base goods are beneficial to plant growth, causing nitrogen increases in the plant; and hypoxanthine and the first two diamino acids act as nitrate sparers. Leucine is also beneficial to plant growth, but the action of tyrosine, in the light of later investigations, is somewhat doubtful. Of the other monoamino acids which may be present in the fertilizer, aspartic acid, glutamic acid and glycocoll have been found to be beneficial. The action of alanine is somewhat doubtful, it apparently being beneficial in low concentrations, while phenylalanine is reported as harmful. The action of cystine on the growth of plants is somewhat doubtful, owing to its insolubility in water. Thus, six of the seven compounds isolated from the base goods are actually available to plants as such and have a beneficial action. Of the monoamino acids, other than the two isolated from base goods, which have been studied in regard to their action on plant growth, three have been found to be beneficial, two doubtful and one is reported as being harmful.

The high-grade nitrogenous fertilizers, such as dried blood, are considered to have a high degree of availability, owing to the fact that the nitrogenous materials when placed in the soil quickly undergo the process of ammonification and nitrification, the nitrogen thus being changed into a form which can be immediately used by the plant. In fact, Lipman (1912) has proposed a method for the determination of the availability of the nitrogen of organic fertilizers, depending on the amount of ammonia produced under biological conditions in a given length of time. It is evident from the investigations here presented that such a method does not tell the whole story, since in the decomposition of protein materials, such as dried blood, intermediate compounds are formed which are undoubtedly of themselves beneficial to plant growth. In order, therefore, to understand the complete action of such nitrogenous fertilizers as base goods, it is necessary to know how the compounds contained in them are acted on by the ammonifying organisms. Jodidi (1912) has shown that amino acids and acid amides are quite readily ammonified when placed in an agricultural soil, the rate of ammonia formation and the amount of ammonia formed depending apparently upon the chemical structure of the particular compound under consideration. In general, he found that the simpler the chemical structure of the nitrogen compound, the more quickly and readily it was ammonified. In the light of these facts, it appears that polypeptides, peptones, proteoses, and proteins would be ammonified still more slowly than amino acids, since their structure is increasingly more complex.

Hartwell and Pember (1912), in their study on the availability of the nitrogen of base goods, by means of plant tests, found that it had apparently as high an availability as dried blood, the water soluble nitrogen having even higher availability. From the nature and amounts of the nitrogenous compounds in base goods this might be predicted. In the case of the dried blood, the nitrogen is practically all in the form of complex protein materials which must be broken down into the simpler compounds by the action of the soil organisms, with the formation of ammonia and other nitrogenous compounds, some or all of which may be of physiological importance to plants. With the base goods the case is a little different; the greater part of the nitrogen is at once available for plant use, and at the same time these available compounds may be changed more quickly and easily by the soil organisms into ammonia and nitrate, which in turn are used by the plant. The soluble nitrogen of the base goods should therefore be in a more readily available form than the nitrogen of dried blood or other nitrogenous fertilizers which are entirely of a protein character.

THE CHEMICAL PRINCIPLES UNDERLYING THE UTILIZATION OF NITROGENOUS TRADE WASTES.

It has already been stated that in order that the plant may make use of the nitrogen of even high-grade organic fertilizers, it is necessary for the proteins therein to be at least partially decomposable by the biological and biochemical agencies of the soil. The low-grade organic nitrogenous fertilizers resist decomposition by these biological and biochemical agencies, and their nitrogen is, therefore, considered to be less available for plant use. The guiding idea behind the processes proposed for the treatment of trade wastes, which will not decompose easily in the soil as such, is to change the nitrogen compounds contained in them in such a way that ammonia is formed and that their decay in the soil is more rapid.

Much of the nitrogenous material in trade wastes is of a protein nature, since the products from which these wastes are derived are of either animal or vegetable origin. Such, for example, is the case with the wastes used in the manufacture of base goods. It has been shown that by the process used in the case of this fertilizer the non-available nitrogenous materials have been made highly available, not only because the nitrogen compounds can be ammonified quickly in the soil, but also because these compounds are directly utilizable by plants. This change in the nature of the nitrogen compounds has been brought about by the partial hydrolysis of the proteins contained in the various trade wastes used in the manufacture of the fertilizer. When proteins decompose through natural conditions, be they in the soil or out of it, a certain amount of hydrolysis of the proteins takes place, and if the decomposition is allowed to proceed long enough under proper conditions complete hydrolysis will result.

The principle involved in making the nitrogenous material in the soil available and in increasing the availability of low-grade nitrogenous material by factory treatment is therefore the same. In other words, the general chemical principle to be applied in making available the nitrogen of low-grade fertilizers, trade wastes, etc., is that of partial or complete hydrolysis by any suitable means of the proteins contained in the wastes. Partial hydrolysis of proteins may be accomplished by means of heat, boiling, steaming, heating under pressure; both partial and complete hydrolysis may be obtained by treating with strong acids or alkalies, either in the cold for a long time or heating to a high temperature, the extent of the hydrolysis depending on the several conditions. An examination of the patent literature shows that all of these means have been proposed for the treatment of trade wastes and other organic materials, although the actual chemical principle of hydrolysis involved in the treatment is not considered. Also, in a number of processes in actual use various of these treatments are practised, resulting in different degrees of hydrolysis of the original proteins. While the availability of the nitrogen of a fertilizer depends on the substances in which the nitrogen is contained, it also depends on the extent of the hydrolysis of the proteins used in the manufacture. It may be stated that in general the more extended and final the hydrolysis, the more available the nitrogen of the compounds formed, since, as has been shown, the final products of hydrolysis are utilized by the plants as such and are at the same time more readily changed into ammonia by soil organisms than are the intermediate compounds produced by partial hydrolysis.

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NOTES FROM THE RESEARCH LABORATORY, EASTMAN KODAK COMPANY.*

THE NATURE AND SPEED OF FLASHPOWDERS.[1]

By John I. Crabtree.

[ABSTRACT.]

A FLASHPOWDER consists of a combustile metal, such as magnesium or aluminum, together with a suitable oxidizing agent, and usually other agents which may accelerate or retard the combustion of the metal, or modify the color of the light produced.

The excellence of any flashpowder is determined by the actinic value of the flash, the amount of noise and smoke produced, immunity of the same to friction or percussion, the nature of the spectrum produced, and the speed of combustion of the powder.

The latter may be easily determined by photographing a sheet of ground glass, illuminated from behind by the flash, by means of a motion-picture camera taking 32 or more pictures per second. The number of images obtained on the film is a direct measure of the speed, while by plotting the densities of each picture a time-intensity curve is obtained. The light intensity usually attains a maximum almost immediately, and then fades away gradually. The effective speed is usually only about half that indicated by the above method, since the photographic effect produced during the latter periods of the flash is almost neglible.

The particular speed of a powder is determined by the composition and fineness of division of the constituents, the quantity and age of the powder used, and the method of igniting the same.

In taking portraits, it is important to eliminate blinking and an unnatural expression of the sitter. Blinking may be avoided by using a powder whose speed of combustion is faster than the time of reflex action of the eye. In this way the portrait is taken before the blink occurs, an effective speed of one-twelfth of a second being usually sufficient to prevent this blinking.

The unnatural expression observed in many flashlight portraits is due to an excessive dilation of the eye-pupils caused by the low light intensity prevailing when the portrait was taken. By focusing under a light whose intensity approaches that of weak daylight, the eye-pupils assume their natural size and a natural expression is thereby obtained.

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* Communicated by the Director.

[1] Communication No. 43 from the Research Laboratory of the Eastman Kodak Company, published in *British Journal of Photography*, January 19, 1917, p. 29.

STELLAR IMAGES ON A PHOTOGRAPHIC PLATE AS AFFECTED BY DEVELOPMENT.[1]

By F. E. Ross.

[ABSTRACT.]

A PRELIMINARY investigation of a two-fold nature: (*a*) determination of differences in power, if any, of various developers in developing faint stellar images; (*b*) determination of differences in quality, if any, of stellar images, depending upon the developer, with special reference to the accuracy of measurement of their distance apart on the plate.

The tests were made by photographing a series of small, round holes in a plate. Under (*a*) above, no certain differences were detected. In investigating (*b*) pyro and caustic hydrochinon (process developer) were tried, development being carried to two and four minutes. From the measurement of 320 distances between images it was establishd that greater accuracy in measurement was secured where the process developer was used; that the lighter development gave best results. This superiority was anticipated, since the appearance of the images was decidedly better for short development in process developer than for any other of those tried.

THE FUNDAMENTAL SCALE OF PURE HUE AND RETINAL SENSIBILITY TO HUE DIFFERENCES.[2]

By L. A. Jones.

[ABSTRACT.]

WHEN radiant energy is incident upon the retina of a normal eye the sensation of light is produced. This sensation may be said to consist of two factors, brightness and color, the former being dependent upon the intensity and the latter upon the quality of the incident radiation. The quality of the radiation may be specified by stating its wave-length, in case radiation of but one frequency is present; or, in case it is composed of a mixture of many frequencies, by stating the wave-length and intensity of each of the component elements. The curve representing the relations existing between the intensity and wave-length of such mixed radiation, commonly called a spectrophotometric curve, is usually plotted with intensity factors as ordinate and wave-lengths as abcissa values.

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[1] Communication No. 47 of the Research Laboratory of the Eastman Kodak Company, published in *Journal, Optical Society of America*, January, 1917.

[2] Communication No. 44 of the Research Laboratory of the Eastman Kodak Company, published in *Journal, Optical Society of America*, January, 1917.

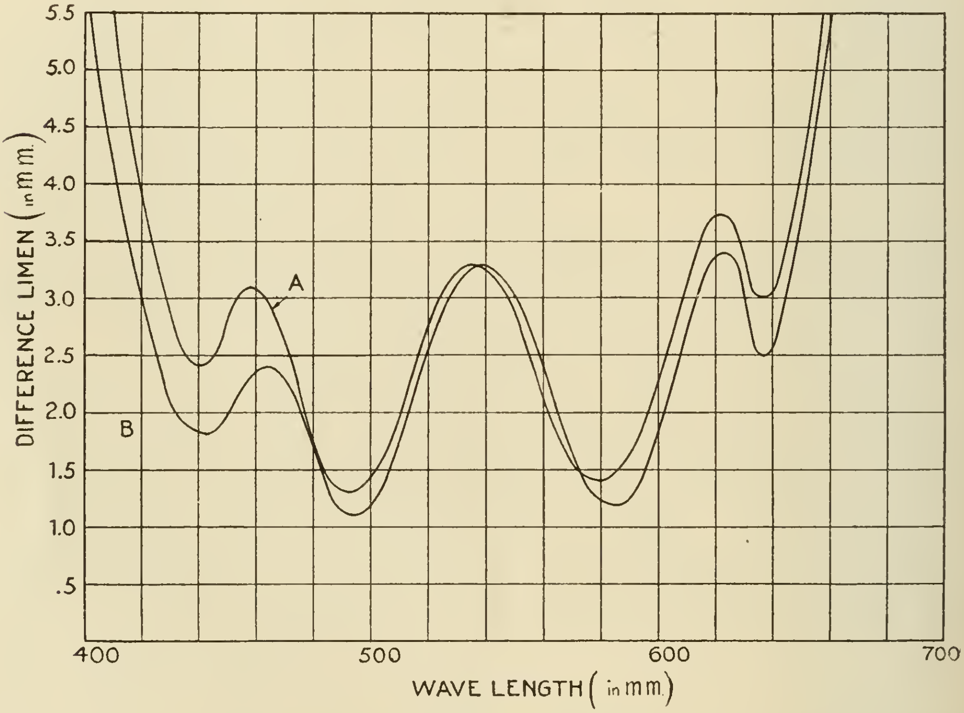
Such a curve constitutes a complete physical specification of the quality of the radiation, and hence of color. The retina, however, being a synthetic rather than an analytic receiving organ, does not recognize the individual component parts of the radiation as such, but receives the mixed radiation as a single stimulus producing a single color sensation. Hence a spectrophotometric curve, while entirely satisfactory from a physical or objective standpoint, does not constitute a physiological specification of the color of the visible radiation, and it is necessary to provide other means for the satisfactory specification of color as such.

Subjectively—that is, from the standpoint of the subjective sensation—color may be said to consist of two factors, hue and purity or saturation. Hue refers to the position in the spectrum of the dominant quality, while purity expresses the extent to which the color departs from the condition of monochromatism. The factors, hue and purity, can be measured directly by color molyzing instrument of the monochromatic type.

It is evident, then, since hue must be expressed in terms of the wave-length of the radiation, that, if a hue scale is to be established, the points on that scale must be designated in wave-length units. The first requirement of a scale for the measurement of any quantity is that the unit used shall be of a fixed magnitude and of the same value throughout the scale. It has been found, however, that equal wave-length differences do not produce equal color sensation differences throughout the sensation scale being considered. Hence the wave-length unit is not suitable for use as a unit in the establishment of a scale of subjective color sensation.

It seems to be most logical, therefore, and in fact the only alternative, to adopt as the unit for such a scale the least perceptible color sensation difference, and to assume that this sensation unit (difference limen) is equal at all points in the sensation scale. The question as to whether or not the difference limen is equal at all points on any sensation scale has been discussed at great length by philosophers and psychologists, and seems to be capable of settlement in either direction by the proper course of metaphysical reasoning. However, from the standpoint of a physicist, it seems entirely reasonable to make the difference limen at all points on a sensation scale equal by definition and to adopt this least perceptible difference as a sensation unit and to use it for the establishment of sensation scales.

FIG. 1.



The first step, then, in the establishment of the fundamental hue scale is the determination of precise values (in terms of wave-length units) for the average normal human eye of the least perceptible hue differences (the sensation unit) throughout the visible spectrum. The final values, then, must be the result of the proper summarization of a large amount of data obtained from the study of a large number of different individuals having normal vision.

Steindler[1] has made measurements on the hue sensibility of twelve subjects, all having normal color vision. It seemed desirable to obtain further data on difference limen of other individuals, and for this purpose the following work was carried out. The measurement of the required difference limen involves the measurement of the difference in the wave-length of the light illuminating two fields which appear just perceptibly different in hue; since the desired scale is that of pure hue, fields illuminated by light as nearly monochromatic as possible must be used. Hence apparatus giving very pure monochromatic light of easily measurable and variable wave-length in connection with some type of two-part photometer field, each part of which may be illuminated independently by monochromatic light of variable quality and intensity, must be employed. It is very important that the intensity be easily controllable, for in making a judgment of equality or difference of hue it is necessary to maintain an intensity balance between the two fields in order that the judgment of hue may not be influenced or confused by the existence of an intensity difference. The first instrument constructed for the fulfilment of these conditions is shown diagrammatically in Fig. 3.

The determination of the difference limen was accomplished by adjusting the angular positions of the two collimating systems, O_1L_1 and O_2L_2, until a just perceptible difference in hue was apparent between the two portions, a,a^1 and b, of the photometric field, and by then obtaining the wave-length difference from readings taken from the calibrated scales, B_1 and B_2. The value thus obtained gave the difference limen for a point in the spectrum midway between the two wave-length values read from the calibrated scales. Several readings were made at each point and at many different points throughout the visible spectrum, a difference limen-wave-length curve being plotted from the values thus obtained.

Many data were obtained with this instrument, which in many ways was found to be very satisfactory, but, due to certain mechanical defects, this was discarded and the work continued with improved apparatus. This consisted of a Brace spectrophotometer used in connection with a Hilger spectroscope of the constant-deviation type. This arrangement permitted of much higher precision in the measurement of the wave-length of the light illuminating the two parts of the photometric field at any time, and also made it possible to set the two fields to an exact color match by means other than the visual judgment of hue.

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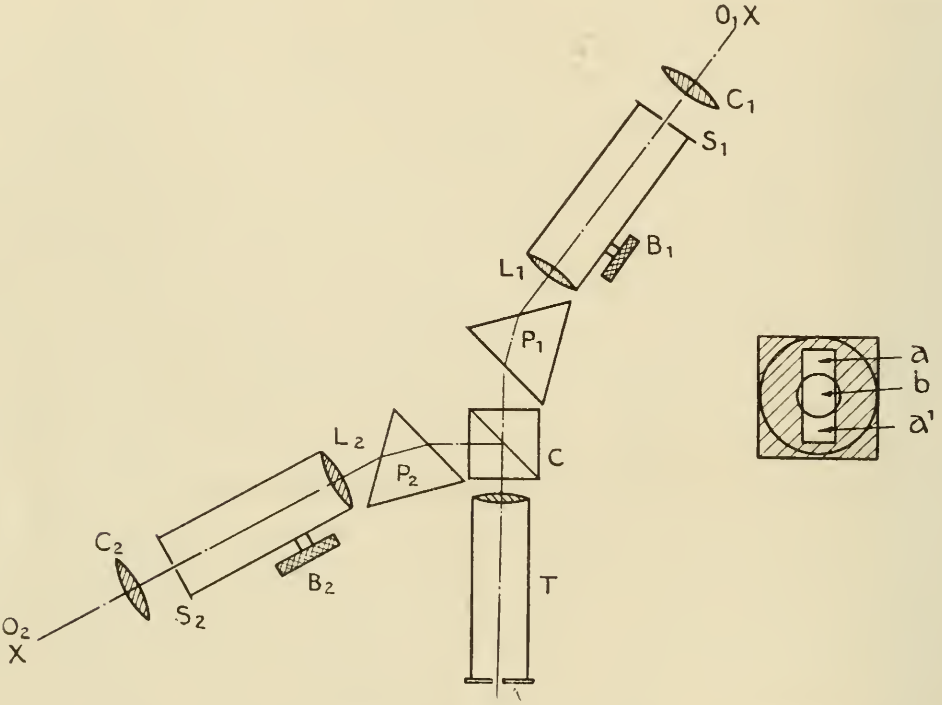
[1] Steindler, O., *Ak. Wiss. Wien.*, 115 IIa Jan., 1906.

In Fig. 5 are shown two complete limen curves, curve A being plotted from data obtained with the first instrument and curve B from limen data taken with the Brace-Hilger apparatus. These curves agree very well in shape and in magnitude of the limen values. They also agree quite well with Steindler's mean curve (Fig. 1), showing the same typical maxima and minima. The limen values agree fairly well with those of Steindler except in the blue end between 400 μμ and 470 μμ. This lack of agreement will be mentioned again later in the discussion.

FIG. 3.

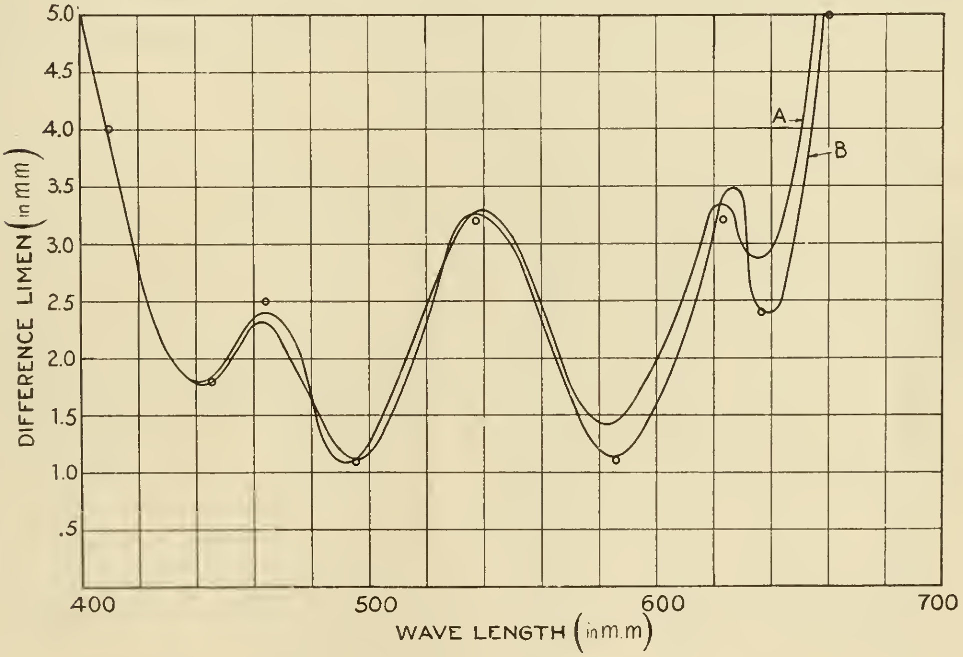


The mean curve obtained by averaging the three sets of data obtained with the right eye is shown as curve B, Fig. 1, in order that its shape and the magnitude of the limen values may be easily compared with the mean of Steindler's data. It will be noted that the values of curve B agree very well with those of A from about 470 to 580 μμ, and that in the red and yellow from 580 to 660 the curve B shows limen values only slightly less than those of A. In the blue end, however, from 410 to 470 the limen values of B are considerably less than those of A. The positions in the spectrum of the various maxima and minima are nearly the same in the two curves.

The results so far indicate that an observer can repeat results on hue limen fairly well, and that the limen-wave-length curve for an individual has a very definite shape.

Now, referring to the scale reading curve, plotted from these same values, in Fig. 6, suppose that a series of points separated by equal intervals be laid off on the hue scale (y axis) and a series of horizontal lines be drawn through these points cutting the scale-reading curve. Now the wave-length values obtained by projecting these points of intersection on the wave-length axis (x axis) will represent a series of spectral hues separated by equal sensation steps. Or, by the inverse process, starting with the wave-length values, it is easy to determine whether any series of hues are separated by equal or unequal sensation steps.

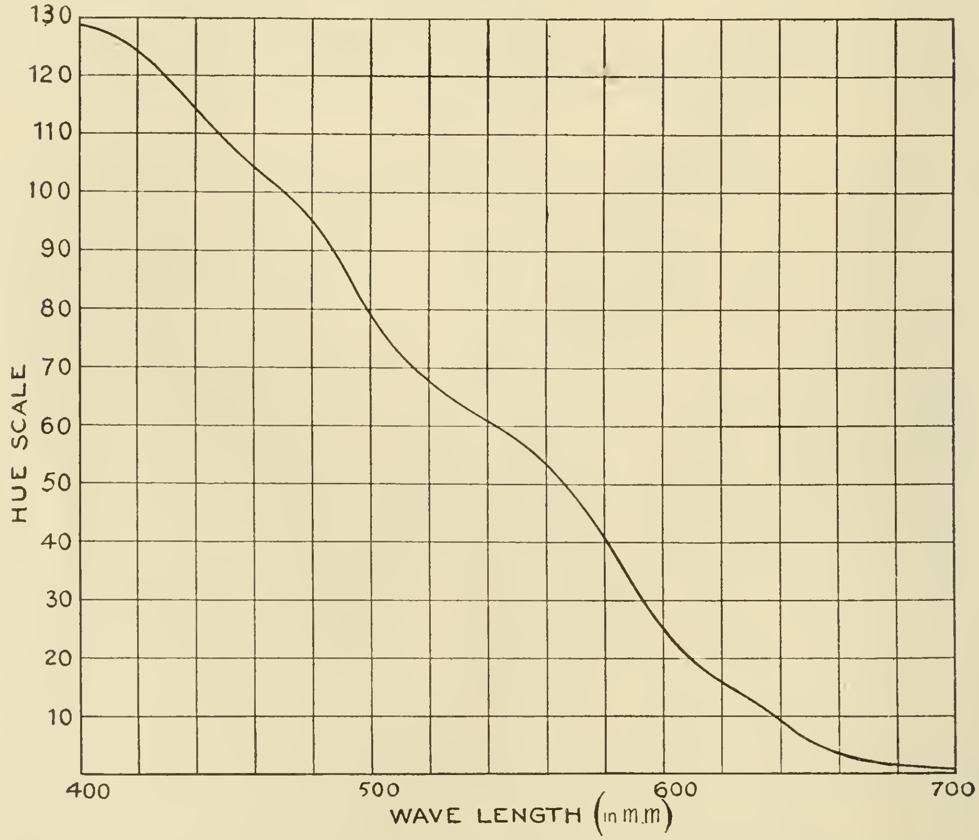
Fig. 5.



This method of analysis has been applied to one of the best systems of color standards. This system was devised and worked out by Robert Ridgway, Curator of the Division of Birds, United States National Museum, and is described in detail and illustrated with 1115 named color standards in his book, "Color Standards and Nomenclature." The system is based on the correct principle of adopting both hue and purity scales based on equal sensation intervals. The scale of pure (spectral) hue consists of 30 units in the visible spectrum, separated by equal sensation intervals, and 6 units spaced through the purples (not present in the spectrum).

In order to determine the spacing on the sensation scale of these 36 hue scale units, it was necessary to measure the dominant hue of each. The actual samples used were cut from sheets obtained from the publisher, and it is entirely possible that some of these may differ slightly from those issued in Mr. Ridgway's book.

FIG. 6.



The colorimetric analyses of the 36 color standards of the hue scale are given in Table I (p. 507). They are numbered (column 1) consecutively, starting with the reddest red and ending with the reddest purple. The names (column 2) are those proposed by Ridgway. The dominant hue values (column 3) are in milli-microns ($\mu\mu$) and the purity values (column 4) are in per cent. white or per cent. hue. In column 5 are given the wave-length intervals, $d\lambda$ (in $\mu\mu$), between the successive samples. In column 6 are given the values, in sensation units, of the corresponding intervals on the sensation scale, determined by use of the scale-reading curve.

The values in column 6 should be equal if the theoretical requirements of a uniformly grade sensation scale are fulfilled by the samples used. The amount of departure from uniformity in these values indicates the extent of failure in the fulfilment of the ideal conditions. The uniformity is quite good considering the practical difficulties encountered in the preparation of color standards.

Many more data are needed for the establishment of the hue sensibility curve of the average normal eye, observations on a larger number of different individuals being required.

TABLE I.

1 No.	2 Name	3 Hue	4 Purity	5 dλ	6 ds
1	Spectrum Red	633	55	..	..
2		616	31	17	5.0
3		610	34	6	3.0
4		605	34	5	2.0
5		...	..	..	2.5
6	Orange Chrome	597	40	8	2.5
7		595	34	2	1.5
8		593	26	2	1.5
9		589	23	4	3.0
10		586	31	3	3.0
11		582	34	4	3.0
12	Lemon Yellow	579	29	3	3.0
13		577	34	2	2.0
14		574	39	3	2.0
15		569	42	5	3.0
16		566	42	3	2.0
17		548	47	18	8.0
18	Emerald Green	521	63	17	9.0
19		518	66	3	2.0
20		510	63	8	3.5
21		495	55	15	10.0
22		490	54	5	5.5
23		486	51	4	3.0
24		484	73	2	1.5

TABLE I.—*Continued.*

1 No.	2 Name	3 Hue	4 Purity	5 dλ	6 ds
25	Spectrum Blue	479	70	5	2.5
26		476	57	3	2.0
27		470	62	6	3.0
28		460	62	10	4.0
29		445	58	15	8.0
30	Spectrum Violet	425	60	20	10.0
					3.8
	Purples.				
31		570	22	..	..
32		559	15	11	6
33		555	13	4	2
34		538	16	17	5
35		534	11	6	2
36		512	9.4	22	8

Colors Applied to Oil and Gas Storage Tanks. ANON. (*Scientific American,* vol. cxvi, No. 6, February 10, 1917.)—In considering the effects of the different types of rays of which light is composed, the calorific or heat-producing rays are conducted by painted or finished objects in a widely varying degree, according to a paper by Henry A. Gardner, presented before the annual meeting of the Pennsylvania State Association of Master Painters and Decorators at Philadelphia. This fact, it is stated, should be studied by the contracting painter who is called upon to paint the enormous area presented by metal oil tanks. Such tanks may contain light distillates which, upon becoming warm, produce highly expansible vapors. When black or dark colored paints have been used, rapid absorption takes place, and considerable losses by evaporation are apt to occur. White or light colored paint should therefore be used for the finishing coat on oil storage tanks. Paints presenting a high gloss are, moreover, less absorptive of thermal rays than those presenting a duller surface.

The experiment was made of exposing a number of small tanks containing benzine, painted in various colors with a gloss finish, to the rays of a carbon arc for a period of 15 minutes. The rise in temperature of the benzine in degrees Fahrenheit was, for black paint, 54° F.; for light gray, 26.3°; for white paint, 22.5°; for aluminum paint, 20.5°; and for tin plate, 19.8°. Although plain tin, on account of its smooth, bright surface, gave the best results, it does not constitute a practical finish, as iron coated with tin corrodes unless protected with paint. Aluminum paint gave very good results, but it is not nearly so serviceable as lead and zinc linseed oil paint.

NOTES FROM RESEARCH DIVISION, ELECTRICAL ENGINEERING DEPARTMENT, MASSACHUSETTS INSTITUTE OF TECHNOLOGY.*

A RESEARCH on "Skin-effect Resistance Measurements of Conductors at Radio-frequencies up to 100,000 Cycles per Second," by A. E. Kennelly and H. A. Affel, has recently been printed in the *Proceedings of the Institute of Radio Engineers*, and has been issued by the Electrical Engineering Department of the Massachusetts Institute of Technology as its Bulletin No. 13.[1] This research is a continuation and extension of preceding M. I. T. researches on skin effect already published.

The research deals with straight loops of copper conductor, the two sides of the loop being parallel, one being the outgoing and the other the return conductor. The source of alternating currents was an Alexanderson high-frequency alternator. The testing current in the loops of conductor was ordinarily 2 or 3 ampères. The testing frequencies ranged from 5000 to 100,000 cycles per second. The conductors included simple round copper wires, copper stranded cords, and copper strips. Two concordant methods of testing were employed. The preferred method involved a particular type of inductive bridge, with the parts fastened on the testing table. The observer had to maintain a constant position at this table during the tests; but, with this precaution taken, metallic shields or enclosures for the testing apparatus were not found requisite. The details of the apparatus are recorded in the paper.

It was found that the skin-effect resistance ratio—*i.e.*, the ratio of a.-c. to d.-c. effective resistance of round copper wires—conformed to the standard Heaviside-Kelvin Bessel-function formulas within the limits of experimental error. There seems to be no reason why this conformity should not exist up to 100,000 cycles per second; but at least there is satisfaction in arriving at the experimental check.

The resistance ratio of a strand of seven bare copper wires, all in contact, but without twist, was found to be the same as that of the equisectional solid round copper wire, within the limits of experimental observation. This and similar observations with straight stranded wires at lower frequencies lead to the inference that the subdivision of a round wire into a round cable of uninsulated parallel contacting strands does not alter the skin-effect resistance ratio.

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* Communicated by the Director.

[1] Copies of this bulletin may be had by addressing The Bursar, Massachusetts Institute of Technology, Cambridge, Mass.

As the parallel strands of the subdivided wire were separated, as by insulating material (enamel, cotton, etc.), the resistance ratio rapidly diminished.

The simple spiralling of the strands of a cord, in one and the same direction, introduced a spirality effect and increased the resistance ratio.

The resistance ratio of a copper strip was found to be usually, but not invariably, less than that of an equisectional round copper wire. The skin effect in strips is greatly increased above that which might be inferred from the thickness of the strip, owing to the existence of " edge effect "; *i.e.,* the tendency of the alternating-current density to increase toward the edges, and to denude the central portions of the strip. The edge effect is a phenomenon closely akin to the ordinary skin effect. In both, the current density increases from the axis of the conductor towards the outlying regions of the cross-section.

Slitting a strip with slits parallel to its length did not appreciably alter the resistance ratio.

Increasing the width of a strip conductor increases the edge effect consequently when rolling a round wire into a flat strip, the resistance ratio is ordinarily first reduced as the strip is made thinner, owing to diminishing skin effect; but, after a certain point, the increasing width of the strip increases the edge effect faster than the skin effect is reduced; so that there is a certain most favorable strip thickness in each case for alternating currents of a given frequency.

Placing the going and returning strips in close juxtaposition, with only a thin strip of paper between their opposed surfaces, reduced the edge effect.

Rolling up the edges of a flat copper strip to form a copper tube with a narrow slit destroyed the edge effect and reduced the resistance ratio to a minimum, dependent only on the strip thickness. It would seem that there is no limit to the reduction of skin-effect extra resistance obtained in this way by using hollow tubular conductors of sufficient wall thickness, provided that they can be mechanically supported. Conductors with braided strands of fine wire, woven stocking-fashion over a non-conducting flexible core, were found to have very small skin effect.

Measurements are now being conducted on single-layer coils or solenoids to determine their resistance ratios at radio frequencies.

The mathematical laws of the edge effect in copper strips of ordinary widths have not yet been worked out, except in the particular case of opposed flat parallel strips separated by insulating layer of relatively small thickness. For this case a simple formula is given, following the results originally published by Lord Rayleigh.

Initiation of Explosions. W. ARTHUR. (*Proceedings of the Engineers' Club of Philadelphia,* vol. xxxiv-3, No. 148, p. 135, March, 1917.)—Until quite recent times, black powders or kindred mixtures were the only explosives in use. The energy they contained was liberated by the burning of the mixture, only the minutest flame being required to start the ignition, as the various components were extremely finely divided, and only a small amount of heat was sufficient to raise them to the ignition point. The beginning of what may be termed internal ignition in contradistinction to the previous method, which may be styled external ignition, followed the discovery of mercury fulminate by Howard in 1799. Its ability to fire gunpowder gave rise about the year 1815 to the development of the percussion cap.

The percussion cap may be briefly described as a small metal capsule containing mercury fulminate or mercury fulminate mixture, or other mixture with similar properties. The cap was used by placing it over the end of a small tube leading to the powder chamber. When struck a sharp blow, the mixture detonated, giving rise to considerable heat and igniting the powder. The significance of this invention was as great as the discovery of gun-cotton or smokeless powder, the use of fixed ammunition in modern firearms having been made possible by a dependable primer. The length and heat of the primer flame will determine very largely the character of explosion of the charge. If the flame be short and the temperature not very high, only a portion of the powder may be burned before the projectile leaves the muzzle of the gun. On the other hand, if the primer flame be long and the temperature high, all of the powder may be fired. Mercury fulminate has for many years held its place as a detonating substance superior to all others. In recent years, however, its place has been threatened by other compounds which bid fair to displace it. One of the most promising of these is lead azide, a salt of hydronitric acid.

The chief characteristic of mercury fulminate which makes it valuable as a detonating agent is the ease with which it can be exploded by simple and ordinary means, and the characteristic mode of pressure development which brings about the explosive decomposition of the charge. A large number of chemicals are violent explosives and many exceed mercury fulminate in explosive power, but are less suitable as detonators, or are not suitable at all. Some are too sensitive to shock or friction, others too unsensitive; mercury fulminate occupies a middle position. Many investigators have attempted to account for the initiating effect of detonating compounds, but so far no fully satisfactory theory of their action has been formulated.

Poor Commutation Traced to Frame Vibration. ANON. (*Electrical World,* vol. 69, No. 8, p. 372, February 24, 1917.)—There are so many well-known possible causes of unsatisfactory commutation that when a commutation trouble occurs with a machine of admittedly good design a trouble seeker is likely to direct his attention to eliminating the most common causes before looking for the more uncommon ones. In one particular instance the generator of a motor generator set, that consisted of a continuous current generator driven by an induction motor mounted on a rather long base, commutated rather badly. The sparking was not sufficiently bad to prevent operating the set, but so long as it continued the commutator could never take a polish.

The operator had checked the speed, voltage, load, polarities, air-gap, field drops, brush sets, brush tensions, brush alignments, brush shift, and also the switchboard instruments, and everything appeared to be perfectly regular. The commutator mica appeared to be flush with the bars, but, as it is sometimes difficult to tell with certainty whether or not mica is a little high, it was decided to slightly undercut it as an experiment. At this time a turbine construction man happened along (turbine men are usually very keen for any condition that is likely to produce vibrations), who noticed that oil was breathing out between the bearing cap and pedestal of the middle bearing. This struck him at once as a case of faulty alignment, with the possibilities and causes of which he was thoroughly familiar.

Two iron wedges were made and driven under the centre of the base on opposite sides of the machine. A relief was immediately noticeable, and the vibration that before had been evident only to the most skilful observer was missed at once. The sound emitted by the machine, especially at the brushes, became entirely different, and all sparking ceased. Investigation disclosed that the base of the machine as originally set was virtually resting on its four corners, so far as the distributing of the weight on the foundation was concerned, and the long span of the base had sagged.

THE FRANKLIN INSTITUTE

(*Proceedings of the Stated Meeting held Wednesday, March 21, 1917.*)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, March 21, 1917.

PRESIDENT DR. WALTON CLARK *in the Chair.*

Additions to membership since last report, 45.

The paper of the evening, entitled "Chemistry and American Industry," was presented by Allerton S. Cushman, Esq., A.M., Ph.D., Director, the Institute of Industrial Research, Washington, D. C. The speaker discussed the subject particularly from the standpoint of the products which were obtained mainly from foreign countries prior to the present war. Considerable attention was given to the production of potash and its various compounds, with respect to which there has practically been a famine in this country since the beginning of the war. Fixed nitrogen and the various purposes for which this product is used also formed an important part of the paper. The speaker particularly called attention to those chemicals and chemical compounds essential to the successful prosecution of war, and spoke frankly of the government's needs in the present crisis.

A series of moving-picture films showing the fixation of nitrogen as carried on at the plant of the Cyanamid Company at Niagara Falls, N. Y., were shown by the courtesy of the Bureau of Economics, of Washington.

The paper was discussed by Mr. A. W. Gibbs, Dr. H. F. Keller, and others.

Mr. Gibbs offered the following resolution, which was unanimously carried:

"Resolved, That in thanking Dr. Cushman for his instructive paper we wish especially to thank him for the frankness with which he has stated our unprepared condition and the reasons for it."

Adjourned.

R. B. OWENS,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(*Abstract of Proceedings of the Stated Meeting held Wednesday, March 7, 1917.*)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, March 7, 1917.

MR. W. C. WETHERILL *in the Chair.*

The following report was presented for first reading:

No. 2688.—Chainomatic Balance.

The following report was presented for final action:

No. 2681.—International Money Machine. Recommended that the

Edward Longstreth Medal of Merit be awarded to the International Money Machine Company for the development of this device, and also recommended that the City of Philadelphia award the John Scott Legacy Medal and Premium to Thomas Bilyeu for his inventions embodied in it.

R. B. OWENS,
Secretary.

SECTIONS.

Mechanical and Engineering Section.—A meeting of the Section was held in the Hall of the Institute on Thursday, March 1, 1917, at 8 P.M.

Mr. J. A. P. Crisfield occupied the chair.

Mr. Crisfield introduced Henry Souther, Esq., Consulting Engineer, Aviation Section, U. S. Army, War Department, Washington, D. C., who delivered a lecture, entitled "Development and Progress in Aviation Motors."

With the help of lantern slides, Mr. Souther briefly reviewed the aëroplane motors that were of real use early in the art, and the progress made both in the United States and Europe (so far as can be obtained from war service experience); the recent evolution in the United States Army, and the vision for the future were also discussed. The lecture did not deal with the thermal efficiency of motors or other technical details except to show the progress in horsepowers considered necessary at different periods and for different purposes. Reference was also made to materials used in motors.

After an interesting discussion, a rising vote of thanks was extended to the speaker.

Adjourned.

T. R. PARRISH,
Acting Secretary.

Electrical Section.—A joint meeting of the Section and the Philadelphia Section of the American Institute of Electrical Engineers was held in the Hall of the Institute on Thursday, March 8, 1917, at 8 P.M.

Mr. Charles E. Bonine and Mr. H. P. Liversidge presided jointly.

C. E. Skinner, M.E., Engineer of Research Division, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., delivered a lecture, entitled "Dielectric Losses in Insulating Materials." Mr. Skinner gave a brief *résumé* of past work done along this line, followed by a description of apparatus and methods used in a fairly elaborate study of the subject at high voltages. Results of tests on various kinds of materials under different conditions were given. The reasons for this study were outlined, showing the importance of this method of valuating insulating materials and structures. Brief reference was made to the research facilities and equipment of the Westinghouse Electric and Manufacturing Company, particularly the extensive new building and equipment which is just being put into operation.

After an interesting discussion by Mr. Charles E. Bonine, Dr. Harold Pender, Prof. Clarence E. Clewell, and others, a rising vote of thanks was extended to Mr. Skinner, and the meeting adjourned.

T. R. PARRISH,
Acting Secretary.

Mechanical and Engineering Section.—A joint meeting of the Section and the American Society of Mechanical Engineers was held in the Hall of the Institute on Thursday, March 15, 1917, at 8 o'clock P.M.

Mr. George R. Henderson, president of the Section, and Mr. Joseph A. Steinmetz presided jointly.

Mr. Henderson introduced Jerome C. Hunsaker, Eng.D., Assistant Naval Constructor, Navy Department, Washington, D. C., who delivered a lecture, entitled "Design, Construction, and Equipment of a Modern Military Aëroplane." Dr. Hunsaker discussed the principles of aëroplane design and their application in modern naval and military aëroplanes. The lecture was fully illustrated with lantern slides and moving pictures.

After an interesting discussion, a vote of thanks was extended to the speaker.

Adjourned.

T. R. PARRISH,
Acting Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(*Stated Meeting, Board of Managers, March 14, 1917.*)

RESIDENT.

MR. H. C. BOOZ, Assistant Chief Engineer, Pennsylvania Railroad Company, Broad Street Station, Philadelphia, Pa.

MR. RONALD G. COOLBAUGH, Mechanical Engineer, Joseph Campbell Company, Camden, N. J.

MR. WILLIAM J. FITZMAURICE, JR., 121 South Alden Street, Philadelphia, Pa.

MR. F. G. GRIMSHAW, Assistant Engineer of Electric Equipment, Pennsylvania Railroad Company, West Philadelphia, Pa.

MR. THOMAS W. HULME, Real Estate Agent, Pennsylvania Railroad Company, Broad Street Station, Philadelphia, Pa.

MR. JOSEPH KOHN, Superintendent, International Tooth Company, and for mail, 2204 Natrona Street, Philadelphia, Pa.

MR. ELISHA LEE, Assistant General Manager, Pennsylvania Railroad Company, Broad Street Station, Philadelphia, Pa.

MR. ARTHUR W. LOWE, Public School Teacher, 1238 Harrison Street, Philadelphia, Pa.

MR. FRANK D. LYONS, 6769 Ridge Avenue, Roxborough, Philadelphia, Pa.

MR. THOMAS S. MARTIN, 3RD, Civil Engineer, 770 North Forty-first Street, Philadelphia, Pa.

MR. FRANCIS F. MILNE, JR., 1714 Spruce Street, Philadelphia, Pa.

MR. W. HEYWARD MYERS, Vice-President, Pennsylvania Railroad Company, Broad Street Station, Philadelphia, Pa.

MR. THEODORE W. REATH, Lawyer, 1201 Commercial Trust Building, Philadelphia, Pa.

MR. GROVER C. SESSLER, Construction Engineer, Midvale Steel Company, Nicetown, Philadelphia, Pa.

MR. W. A. SHMIDHEISER, Mechanical Engineer, 6017 Pine Street, Philadelphia, Pa.

MR. W. HINCKLE SMITH, Banker, 201 Liberty Building, Philadelphia, Pa.

Dr. Walter T. Taggart, Department of Chemistry, University of Pennsylvania, Philadelphia, Pa.

Mr. Benjamin Chew Tilghman, 7913 Crefeldt Street, St. Martins, Philadelphia, Pa.

Mr. M. Trump, Civil Engineer, Special Assistant to General Manager, Pennsylvania Railroad Company, Broad Street Station, Philadelphia, Pa.

Mr. Samuel T. Wagner, Civil Engineer, Chief Engineer, Philadelphia and Reading Railway Company, Reading Terminal, Philadelphia, Pa.

NON-RESIDENT.

Mr. J. R. Alexander, General Road Foreman of Engines, Pennsylvania Railroad Company, Altoona, Pa.

Mr. C. D. Barrett, Master Mechanic, Pennsylvania Railroad Company, Sunbury, Pa.

Prof. G. H. Brown, Director, Department of Ceramics, Rutgers College, New Brunswick, N. J.

Mr. S. H. Church, President, The Carnegie Institute, Pittsburgh, Pa.

Mr. J. L. Cunningham, Master Mechanic, Pennsylvania Railroad Company, Harrisburg, Pa.

Mr. R. L. Ettenger, Consulting Mechanical Engineer, Southern Railway Company, 1300 Pennsylvania Avenue, Washington, D. C.

Mr. W. C. A. Henry, Superintendent Motive Power, Pennsylvania Lines West of Pittsburgh, Columbus, Ohio.

Mr. George B. Koch, General Foreman, South Altoona Foundries, Pennsylvania Railroad Company, Altoona, Pa.

Mr. J. Kruttschnitt, Civil Engineer, Railroad Executive, Southern Pacific Company, 165 Broadway, New York City, N. Y.

Mr. T. A. Lawes, Mechanical Engineer, The New York, Chicago and St. Louis Railroad Company, Cleveland, Ohio.

Mr. C. L. McIlvaine, Master Mechanic, New York, Philadelphia and Norfolk Railroad Company, Cape Charles, Va.

Mr. D. R. MacBain, Superintendent Motive Power, New York Central Railroad Company, Cleveland, Ohio.

Mr. H. H. Maxfield, Superintendent Motive Power, Western Pennsylvania Division, Pennsylvania Railroad Company, Pittsburgh, Pa.

Mr. J. Milliken, Superintendent Motive Power, Philadelphia, Baltimore and Washington Railroad Company, Wilmington, Del.

Mr. Allen E. Nichols, Civil Engineer, 5331 Woodlawn Avenue, Chicago, Ill.

Mr. J. L. O'Donnell, General Superintendent, Pennsylvania Railroad Company, Pittsburgh, Pa.

Mr. F. N. Pease, Chief Chemist, Pennsylvania Railroad Company, Altoona, Pa.

Mr. G. L. Peck, Vice-President, Pennsylvania Lines West of Pittsburgh, 903 Pennsylvania Station, Pittsburgh, Pa.

Mr. C. H. Quinn, Chief Electrical Engineer, Norfolk and Western Railway Company, Roanoke, Va.

Mr. Ellis B. Ridgway, Manufacturer, Coatesville, Pa.

Mr. A. T. Smith, The R. U. V. Company, Inc., 50 Broad Street, New York City, N. Y.

MR. EDWARD B. TAYLOR, Vice-President, Pennsylvania Lines West of Pittsburgh, 901 Pennsylvania Station, Pittsburgh, Pa.

MR. E. T. WHITER, Assistant General Manager, Pennsylvania Lines West of Pittsburgh, Pennsylvania Station, Pittsburgh, Pa.

MR. G. H. WOODROFFE, Mechanical and Metallurgical Engineer, Parkesburg Iron Company, Parkesburg, Chester County, Pa.

ASSOCIATE.

MR. WILLIAM J. BURGESS, 940 South Fifty-fifth Street, Philadelphia, Pa.

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MR. JOHN H. BARR, 374 Broadway, New York City, N. Y.

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MR. JOHN GAREY, care of American Dyewood Company, Howell Street, Chester, Pa.

MR. CLARENCE A. HALL, Pelham Court, Germantown, Philadelphia, Pa.

MR. PENROSE R. HOOPES, 41 Hough Avenue, Bridgeport, Conn.

MR. D. W. LUM, P. O. Box 1808, Washington, D. C.

MR. JULIAN S. SIMSOHN, Hotel Majestic, Broad Street and Girard Avenue, Philadelphia, Pa.

MR. L. H. THULLEN, 30 Post Avenue, New York City, N. Y.

MR. JOHN C. TRAUTWINE, 3RD, 3943 Locust Street, Philadelphia, Pa.

NECROLOGY.

Mr. E. Eldridge Pennock was born July 9, 1857, and died on March 4, 1917. He was educated in private schools. Early in life he entered the employ of Francis H. H. Brook, a prominent grain merchant. He afterward formed a partnership with his employer, the firm being known as Brook & Pennock. Upon the death of Mr. Brook, Mr. Pennock continued the business under the name of Pennock & Company.

He was a member of many social organizations and clubs. Mr. Pennock became a member of The Franklin Institute on April 9, 1913.

Mr. John W. Steacy was born at Strasburg, Lancaster County, Pa., on June 9, 1833, and died at York, Pa., March 2, 1917. He was educated in the public schools and at Strasburg Academy.

In the first thirty years of his active life he was connected with a number of business enterprises, including iron and oil companies.

In 1878 Mr. Steacy became manager of the York Rolling Mill. This was reorganized in 1886, and became a joint stock company. In 1899 a consolidation of the more important rolling mills and furnaces took place, and Mr. Steacy became general manager of the new corporation.

In 1903 he withdrew from the concern and devoted his entire attention to the construction of suburban trolley lines around the city of York, Pa.

He was prominently identified with the civic, business, and charitable interests of the city of York.

Mr. Steacy became a member of The Franklin Institute on May 7, 1903.

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BOOK NOTICES.

Bridge Engineering, by J. A. L. Waddell, C.E. In two volumes, 8vo., cloth, 2177 + lxxv pages, 560 illustrations, and 90 tables. John Wiley & Sons, Inc., New York, 1916. Price, $10.

Under a brief but appropriately comprehensive title, Dr. Waddell has made a most important and unique contribution to engineering literature. In judiciously arranged sequence, he has formulated a code of practice embodying all the information he has been able to accumulate concerning every branch of bridgework during a practice of forty years, and few have earned an equal right to speak with authority on the subject.

Covering the topics embraced in the elements of many types of bridges, coupled with a great wealth of data and discussion, the work is necessarily voluminous. Sixty pages are devoted to a table of contents and lists of figures, diagrams, and tables; 1893 to text; 224 to a glossary of bridge engineering terms, and 61 to an index. Primarily the work is addressed to the younger members of the profession, to whom it will undoubtedly prove a valuable guide in avoiding the many pitfalls that confront anyone whose judgment is not ripened by wide experience. Besides, the copious information of a general nature scattered throughout the work should make it useful to men whose duties are of an administrative nature who may not be engineers, as well as to executives who may require authoritative information.

It is fair to assume that many engineers will differ from Dr. Waddell or will be unwilling to follow him closely. To such there is at least much value in the suggestion and challenge of his forceful statements and discussions. Probably the most valuable assistance to the bridge engineer is the extensive collection of tables and cross-section diagrams, most of which are the accumulation of many years of varied professional practice. Of much interest are the discussion and diagrams showing the comparative weights and cost of bridges built of carbon steel and mixed nickel and carbon steel, and of these materials with a "purified" steel made in France, and with other alloy steels. Loads are elaborately discussed and amply illustrated with numerous diagrams. The loads from electric locomotives and the possibility of resulting unprecedentedly heavy concentrated loads have apparently been omitted.

Chapter XVIII, dealing with "Shop Work as Affecting Bridge Design," includes points suggested by two eminent engineers of bridge manufacturers, whereby economy is effected in manufacture and erection, and a discussion by the author. Chapter XLV, on "Expedients in Design and Construction," has numerous examples of the importance of the ingenuity and originality that may be exercised in handling many problems of design and construction. Chapter LXXVIII and LXXIX cover the "General Specifications of Design" and of "Manufacture and Erection," respectively, and are most complete. It may be noted, however, that they do not cover the special condition to be met when bridges are to be exported to foreign countries where facilities for transportation and erection may require special construction and design.

The final glossary of terms is extraordinarily complete, and contains those terms common among workmen and rarely found in books, which are unknown to the foreign engineer and not always known to the experienced engineer in this country.

Throughout the work frequent references are made to other leading authorities, and ample credit is given to engineers from whom he quotes, including those who differ from him. The work tells the life-story of an extensive, varied, and successful career; and, while it contains much matter for discussion and dispute, it is indeed a valuable contribution to the profession and a fitting climax to the active business life of the able author.

PERCY S. HILDRETH.

PRINCIPLES OF QUANTITATIVE ANALYSIS: An Introductory Course, by Walter C. Blasdale, Ph.D. New York, D. Van Nostrand Company, 1917. Second edition. 388 pages, 70 illustrations, contents, tables, and index. 12mo. Price, $2.50 net.

A second edition that follows the first in about two years needs no special encomiums from a reviewer, for it is evident that the work has been acceptable to those for whom it was intended. The book is written in full accord with the modern theories of physical chemistry, and illustrates vividly how useful these theories are in their practical application. The subject-matter is largely concerned with inorganic chemistry, but a few processes that are usually included in commercial organic analysis are given. The theory and practice of each procedure are carefully explained, and some problems are given in connection with each important section. It might be an advantage to indicate, in connection with each problem, the pages on which the data available for the solution thereof are to be found, but, as the book will be almost entirely used in association with competent instructors, this is possibly a minor matter. I am pleased to see that Dr. Blasdale has the courage and good judgment to write "thru" and "thruout," and regret that he does not see his way clear to drop the useless final "e" in the many chemical terms in which it occurs. Especially it is to be regretted that "glycerol" is termed "glycerine." Even that last text-book citadel of conservative orthography, the U. S. Pharmacopœia, has dropped the final "e" in this word.

The book is excellently printed, of convenient size and shape, on good paper, and well illustrated.

HENRY LEFFMANN.

PRACTICAL PHYSIOLOGICAL CHEMISTRY: A Book Designed for Use in Courses in Practical Physiological Chemistry in Schools of Medicine and of Science, by Philip B. Hawk, M.S., Ph.D., Professor of Physiological Chemistry and Toxicology in the Jefferson Medical College of Philadelphia. Fifth edition, revised and enlarged. 638 pages, illustrations, plates. 8vo. Philadelphia, P. Blakiston's Son & Company, 1916. Price, $3.

Five new chapters have been inserted in this edition. One chapter is devoted to the nucleoproteins and nucleic acids and their constituents, and to the enzymes which produce biochemical changes in these compounds. The chapter on gastric analysis contains a discussion of hydrogen ion concentration and titratable acidity, the determination of hydrogen ion concentration by indicators, and the fractional method of gastric analysis, including the use of the stomach-tube of Rehfuss. The chapter on intestinal digestion is devoted exclusively to digestive processes brought about by enzymes which have their origin in the intestine. Among the subjects presented in the chapter on blood analysis, mention should be made of the following: New methods for the determination of the various nitrogenous constituents, sugar, acetone bodies, chlorides, lipins, the hydrogen ion concentration (by means of phenolsulphonephthalein); the description of the nephelometer and its use in blood analysis. In the chapter on metabolism, an elaborate series of experiments is given, involving the manipulation of either or both the urine and the fæces. In addition to the new chapters, just reviewed, additions to the text have been made throughout the volume, including the Van Slyke and the ninhydrin methods for the determination of amino nitrogen, the nephelometric estimation of milk proteins, the phenolsulphonephthalein renal function test, the determination of the hydrogen ion concentration of urine by indicators, micro methods for the nitrogenous constituents of the urine, the urease method for the determination of urea, and the colorimetric determination of phenols by means of phospho-tungstic and phospho-molybdic acids. In all the chapters the analytic methods have been rearranged in sections on principle, procedure, calculation, and interpretation. The laboratory procedure in the most important tests and methods is printed in blackface type for convenience of reference.

The demand for this book is shown by the fact that during one decade five editions have appeared, and one edition has been reprinted twice.

JOSEPH S. HEPBURN.

MICROBIOLOGY: A Text-Book of Microörganisms, General and Applied. Edited by Charles E. Marshall. Philadelphia, P. Blakiston's Son & Company, 1917. Second edition, revised and enlarged. 861 pages, contents and index. 12mo. Price, $3 net.

Twenty-five specialists, American and foreign, have assisted Professor Marshall in the preparation of this book, which is packed with a large amount of the most interesting and important information. The success of the first edition has shown the merit of the work. There is scarcely a department of science in which modern development has been of more practical value to the human race than that covered by this work. In consideration of topics it ranges from data concerning microörganisms in important industries, such as wine and vinegar manufacture, to the study of the diseases affecting insects. The latter subject is closely connected with the production of food, for many insects are destructive to food animals and food plants, and the destruction of such pests has been accomplished by cultivating the specially antagonistic microörganisms. An instance is the fungus that destroys the common house-fly. One of the most important instances of insect infection of a serious nature is the disease of the silkworm, which Pasteur investigated in 1869 and against which he introduced effective measures.

Although prepared as a text-book, the work is well adapted for perusal by the non-professional who desires to get information as to the multiplicity of enemies that man and his supporting animals have in the microscopic world. Not all minute organisms, however, are hostile, and the friendly ones are also given good notice.

The book is well printed on good paper and of convenient size.

HENRY LEFFMANN.

ANNUAIRE POUR L'AN 1917. Publie Par le Bureau des Longitudes. Paris, Gauthier-Villars & Company, 1917. 700 pages, illustrations, portraits, maps. 16mo. Price, two francs.

This well-known annual contains in the present issue the usual astronomical, meteorologic, and metrologic data, with three special essays of much interest: The Babylonian Calendar, by G. Bigourdan: The Advance of Legal Time during the Summer of 1916 (Daylight-saving), by J. Renaud, and The Valuation of the Meter in Terms of Wave-lengths of Light, by M. Hamy.

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Interior Wiring and Systems for Electric Light and Power Service: A manual of practice for electrical workers, contractors, architects, and schools, by Arthur L. Cook, head of Department of Applied Electricity, Pratt Institute. First edition. 416 pages, illustrations, diagrams, 16mo. New York, John Wiley and Sons, 1917. Price, $2.

Physical Laboratory Experiments for Engineering Students, by Samuel Sheldon, Ph.D., D.Sc., and Erich Hausmann, E.E., Sc.D. Part i, Mechanics, Sound, Heat and Light. 134 pages illustrations 12mo. New York, D. van Nostrand Company, 1917. Price, $1.25.

Canada Department of Mines, Mines Branch: Feldspar in Canada, by Hugh S. deSchmid, M.E. 125 pages, illustrations, plates, maps. Researches on Cobalt and Cobalt Alloys, conducted at Queens University, Kingston, Ontario, part iv, Cobalt Alloys with Non-corrosive Properties, by Herbert T. Kalmus, B.Sc., Ph.D., and K. B. Blake, B.Sc. 37 pages, illustrations plates, 8vo. Ottawa, Government Printing Bureau, 1916.

United States Bureau of Mines: Bulletin 128, Refining and Utilization of Georgia Kaolins, by Ira E. Sproat. 59 pages, illustrations, plates, 8vo. Bulletin 143, Abstracts of Current Decisions on Mines and Mining Reported from May to August, 1916, by J. W. Thompson. 71 pages, 8vo. Coal-mine Fatalities in the United States, 1916, compiled by Albert H. Fay. 42 pages, 8vo. Technical paper 165, Quarry Accidents in the United States during the Calendar Year 1915, compiled by Albert H. Fay. 77 pages, plate, 8vo. Technical paper 168, Metal-mine Accidents in the United States during the Calendar Year 1915, compiled by Albert H. Fay. 114 pages, 8vo. Washington, Government Printing Office, 1916–'17.

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North Carolina Geological and Economic Survey: Press Bulletin No. 156, The Ash in North Carolina. 8 pages, 8vo. Some Facts and Figures about North Carolina and her Natural Resources. Second edition. 51 pages, 24mo. Raleigh, State Printers, 1917.

Temperature Measurements in Bessemer and Open-hearth Practice, by George K. Burgess, Sc.D. 13 pages, 8vo. Preprint from Transactions American Institute of Mining Engineers, February, 1917.

India's Appeal to Canada, or an Account of Hindu Immigration to the Dominion, by a Hindu-Canadian. 16 pages, 8vo. Toronto, Canada India League, 1916. Price, 10 cents.

Colorimetric Test for Organic Impurities in Sands, by Duff A. Abrams, professor in charge of laboratory, and Oscar E. Harder, chemist. Circular No. 1, Structural Materials, Research Laboratory, Coöperation of Portland Cement Association and Lewis Institute. 7 pages, 8vo. Chicago, Lewis Institute, 1917.

Your Streets: Concrete for Permanence. 34 pages, illustrations, 8vo. Chicago, Portland Cement Association, 1917.

Insulation of Transmission Lines Near Cement Mills. ANON. (*Electrical World,* vol. 69, No. 8, p. 372, February 24, 1917.)—In a number of instances successful service has been maintained on lines serving or passing cement mills by the simple expedient of extra insulation. It has been recommended in the case of 44,000-volt lines that twice the standard number of disks should be used per string, and periodically the line should be killed and the insulator disks carefully wiped with a cloth saturated with transil oil. For 60,000-volt lines, in addition to doubling the normal number of disks, duplicate lines have sometimes been constructed in the vicinity of a mill, so that the service need not be interrupted when the insulators are being cleaned, as power can be supplied over one branch while the other branch is dead. These methods of using double insulation to safeguard service have proved equally successful in regions where salt deposit is heavy.

CURRENT TOPICS.

German and Austrian Heavy Field Artillery. F. T. Hines. (*Journal of the United States Artillery,* vol. 47, No. 1, p. 70, January-February, 1917.)—The German and Austrian military authorities early foresaw the controlling effect of heavy mobile field artillery in future warfare, and they prepared accordingly. Their early successes and their present unbroken front are largely due to their possession of numerous heavy howitzers, of which the Allies, for the first year at least, possessed practically none. Long before the war, and at least in 1908, funds (some $2,000,000) were obtained by the German military authorities for a competitive test of various types of heavy ordnance on auto-trucks or of their transportation by tractors. Exhaustive tests were made in that year and also during 1911, which resulted in the formation of auto-truck companies or batteries of heavy field and siege artillery. It is now known that the German forces had 42-cm. (16.5-inch) mortars, manufactured, no doubt by the Krupps, some time before the war, and considerable confusion has occurred between this German 42-cm. mortar and the Austrian 305-mm., commonly referred to as the " Skoda."

The Skoda howitzer was developed by the Austrian authorities before the war broke out, and it is to them that the reduction of the Belgian forts and those of Przemysl is largely due. They have proved very accurate and their shells have terrific effect, both against fortifications and troops in the field. They fire a shell weighing 860 pounds with a muzzle velocity of 1115 foot-seconds, their maximum range being 14,000 yards. They are very mobile and can be mounted in 24 minutes and entirely dismounted and moved away in 40 minutes. They are transported in sections on tractors at a rate of 12 miles per hour. These tractors are drawn by a Skoda-Daimler car of 100 horsepower with four driving wheels, and at low speed can go up a 16 per cent. grade. From data available, it appears that the recoil of the Skoda mortar is taken up by oil cylinders, and is returned into battery by compressed air. The piece is set on a portable foundation when the ground is soft. When the foundation is used the piece can be traversed 60 degrees on each side of the median line; without the foundation, a slightly less angle of traverse is possible.

Data available would seem to indicate that the German forces have two very different types of 42-cm. mortars or howitzers: one transported by motor trucks, the other on railway cars. The latter type is more powerful than the former, and is placed on a concrete base, while the former is fired from its wheeled carriage. The first of these is a graceful and well-proportioned piece of ordnance, 5 metres in length, with a bore of exactly 42 cm. between lands. The shell weighs about 1800 pounds. The most effective range is about 10,200 yards, though the maximum range is much greater. The second type is permanently mounted on a specially designed railway truck from which it is fired. The piece is put in battery by chocking the platform on the track and on the ground by means of hydraulic jacks so as to take the weight completely off the trucks. It fires a projectile weighing about 1980 pounds with a bursting charge of 264 pounds of picric acid or trinitrate of toluene, and has a range of 15,300 yards.

Electricity from Wind Power. F. S. CULVER. (*Electrical World,* vol. 69, No. 8, p. 367, February 24, 1917.)—Generation of electricity by wind power is a problem that has been studied by numerous inventors for many years, yet very few of them have compiled data which can be used in the design of small rural lighting plants. Furthermore, most of the arrangements which have been tried out have been abandoned owing to their complexity, inefficiency, or cost. Believing that there would be a field for wind-power generators, however, if a simple and durable construction could be developed, the writer installed two experimental plants in Wisconsin and conducted extensive tests to determine the best method of utilizing the wind.

One of these plants was erected on a farm in northern Wisconsin. A rough estimate of the number of lamp-hours required showed that a battery of 26 cells having a normal discharge rate of three ampères for eight hours would be ample to provide lighting for several nights on one full charge. For charging the battery, a generator rated at three ampères and 65 volts was selected. From information obtained on wind velocity it was decided to erect an ordinary pumping form 12-foot windmill on a 50-foot steel tower. Regulating features of the windmill limited its maximum velocity to 75 revolutions per minute. To assure charging with winds of low velocity, a generator was selected having a normal speed of 900 revolutions per minute but having a pulley ratio which made it operate at 1800 with the maximum windmill speed of 75 revolutions per minute. Heavy charging current was prevented by a differential winding. An automatic cut-in connects the generator with the battery whenever the generator voltage is in excess of the battery voltage, and breaks the circuit just before the current reaches zero value or point of reversal. A waterproof generator was employed, being attached to the turn-table of the windmill below the axis and a little to one side, driven by a sprocket-wheel and standard automobile chain. Connections were made by means of collecting brushes attached to the stationary framework of the windmill.

Although mounting the generator at the top of the windmill affords a very efficient drive, the generator is inaccessible. It was therefore decided to erect another experimental plant in which the generator would be placed in a building in the base of the tower. The second plant was erected in southern Wisconsin and consisted of a 12-foot wheel mounted on a 50-foot tower driving a six-ampère, 35-volt generator at 900 revolutions. The battery used with this equipment was rated at six ampères and consisted of 14 cells. A standard windmill with a vertical shaft terminating in a footjack was employed, and bevel gears were used to transmit power to a horizontal shaft extending into the building. The generator was driven from this shaft by an ordinary pulley and belt.

Both of these plants proved of ample capacity for the work required and of equal efficiency and cost, but the second plant has the advantage of greater simplicity and suggests the possibility of using this system in connection with any power windmill that may be already in use. Some of these plants have been in operation for six years, furnishing illumination every night, and there seems to be no question of their durability.

Spray Irrigation. M. B. WILLIAMS. (*U. S. Dept. of Agriculture, Bulletin 495,* February 14, 1917.)—Within the past two years spray irrigation, one of the most recent methods of applying water to crops to be adopted in the United States, has come into use over a wide area, especially in the Atlantic coast states. Among other advantages of spray irrigation, it may be satisfactorily used on both light and heavy soils, and on hillsides as well as on level ground. By this system water may be applied very lightly to delicate crops and plant seedlings, or, when weather conditions require, as a slight supplemental supply of moisture, and, on the other hand, it may be applied heavily during protracted dry periods. Where economic conditions are favorable to the adoption of spray irrigation, the most important question then becomes the possibility of securing an adequate water supply. Since the system is in use chiefly in the humid or semi-humid regions, practically all installations are made by individuals and do not involve the development and transportation of distant supplies, as is common for community irrigation in the arid regions. The sources of water supply for spray systems may be streams, springs, stored run-off, sumps for catching drainage water, and wells. In some sections of the East the storage of water falling on the roof of a building during the summer months is sufficient to irrigate a garden which is three times the area of the building. The reservoir in this case would need to hold about two months' rainfall, or the equivalent of six inches, falling on the roof.

Three types of spray irrigation construction have been employed more or less widely for field irrigation. The hose and movable nozzle, or movable lines, fed from an underground pipe system and hydrant, was one of the earliest systems to be developed and is still in rather extensive use for the irrigation of cold-frame and hot-bed crops, garden setting and seed beds, etc. Though the first cost of such a system is lower than that of the other types, it is the least efficient. Stationary nozzles on vertical, equidistant standards, varying from four to six feet in height for truck to a height greater than the trees in orchards, constitute a second type of spray irrigation system. The nozzles are set from 30 to 50 feet apart. The advantages of this system are rapidity of application where this is desirable, comparative freedom from clogging, and satisfactory operation at low pressures. The disadvantages are uneven distribution of water due to uneven spread of nozzles and the overlapping of circular sprayed areas, and lack of adaptability to more delicate crops. The cost of installation is more than that of the movable hose system.

The stationary overhead system, the third type of spray irrigation, consists of raised parallel lines of pipe in which nozzles are set every few feet. The pipe lines may be rotated so that the spray will be directed at any desired angle between the vertical and 45 degrees on either side of the line. In this way areas about 50 feet wide can be watered by each line. The advantages of this type of spray system are adaptability to varying needs and evenness of distribution. The cost is about the same as that of the fixed nozzle system.

Machine Rifles. S. TRACK. (*Arms and the Man,* vol. lxi, No. 23, p. 443, March 1, 1917.)—Should the United States, ten years hence, be called upon to provide an army for active field service, there is little doubt that the weapons of the riflemen therein will be as different from the 0.30-calibre service arm as is the Springfield from the 60-inch Kentucky rifle of frontier days. While the present service rifle marks the high-water mark of development, ballistically, ordnance experts are bending every energy toward the selection of machine guns with which to equip the nation's fighting forces, and batteries of light and heavy rapid firers will play as important a part in future battles as light and heavy artillery have in the past. It is a generally-accepted belief that light and heavy types of rapid firers, capable of 300 to 700 shots per minute, will constitute the chief reliance of infantry campaigns in the future. If that prove true, it is considered likely that the heavy guns will probably be Vicars-Maxim, water-cooled, and Colts, each weighing in the neighborhood of 50 pounds with tripod. The lighter type will probably be Lewis guns, weighing 25 pounds, and Benet-Mercier guns, which weigh considerably more than the Lewis, together with a possible third type, the so-called portable Hotchkiss, weighing only 16 pounds, which will shortly be submitted to the United States for trial.

It is by no means certain, however, that the true machine gun will entirely remove the necessity of developing a smaller weapon of offence and defence, less effective in mass fire, perhaps, than the machine gun, which will be, in all probability, an adaptation of machine-gun principles to the army rifle—in short, a machine rifle.

An attempt is already being made to supply such a weapon. Not very long ago one was submitted to the War Department. This rifle, while capable of functioning in every way claimed for it by its sponsors, was not accepted, chiefly because it weighs 10½ pounds. The ordnance experts believe that to be practical a machine rifle should weigh no more than 9½ pounds. The gun, a Hotchkiss, was manufactured at the Coventry, England, plant of that concern, and was designed to be purely and simply a shoulder gun, and is equipped with a bayonet. It is claimed that this machine rifle can be loaded with a 10-cartridge clip for rapid fire in less time than is consumed in loading the Springfield with its five-cartridge clip, and that a maximum rapidity of 100 shots per minute can be attained.

Inflammability of Carbonaceous Dusts. H. H. Brown. (*Journal of Industrial and Engineering Chemistry,* vol. 9, No. 3, p. 269, March, 1917.)—The fact that coal-dust is explosive is very generally known to-day, though only within the last thirty years has it been fully recognized that coal dust alone is explosive without the presence of gas. Experiments have shown that many other carbonaceous dusts are at least as easily ignited and capable of propagating an explosion as coal-dust. While most of the dust explosions reported in surface plants occur in mills and elevators handling wheat, oats, and corn and their products, it appears that no mill handling carbonaceous material is immune from the possibility of explosion. The list of known explosions in other kinds of mills includes those handling dextrine, sugar, starch, malt, wood, linseed meal, cottonseed meal, paper, cork, fertilizer, sulphur, cocoa, and spice dusts.

That flour dust will explode was clearly demonstrated in 1878 by a tremendous explosion in the Washburn Flour Mills in Minneapolis. This disaster aroused milling men to the danger of existing conditions and caused many to take immediate precautions against a repetition of a similar occurrence. The impression was not lasting, and, although a large number of grain-dust explosions occurred later, general interest was not awakened until June 24, 1913, when an explosion occurred in a feed-grinding plant at Buffalo in which 33 men lost their lives and over 70 men were injured. This explosion, which occurred during the ordinary process of milling, completely destroyed the mill and considerably damaged the surrounding property. As a result, an agitation was started between the millers and the Bureau of Mines for the investigation of questions relating to explosions of grain dust. This was later taken up by the Government and is being continued in coöperation between the Bureau of Chemistry and the Bureau of Mines.

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ENZYMES IN THE FERMENTATION INDUSTRIES.*

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I INVITE you to-night for a brief excursion into a chemical field more than others shrouded in humbleness and lack of obviousness. The difficulties with which it teems become, however, far outbalanced by the magnificent vista of large and glorious problems, problems that aim at increasing our present powers over nature ten- and a hundred-fold!

When we use the term "powers of nature" we are inclined to have in mind something grand or forceful, like lightning, the Falls of Niagara, or some other striking phenomenon. But we meet nothing of the kind when getting in touch with the powers wielded by the enzymes. They are more like in the days of Elijah, when we are told that God was not in the torrent nor in the lightning, but in the "still, small voice."

What are these powers? Where are these enzymes? What do they do?

Their very existence has been known only for a few decades. And yet we know to-day that, for instance, on infliction of even a slight wound all the blood would have to run out from our body as water does from a leaky cask if it were not for an enzyme, Thrombase, by which the blood is caused to curdle on contact with

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air; that we could not make cheese from milk, because likewise minute quantities of another enzyme, chimase (one part of this enzyme to 800,000 parts of milk), must intervene and cause coagulation; that there could be no butter fat either but for the enzyme action; that, in fact, not only all the important bodies on which we subsist, such as sugar, starch, albumin, meat, etc., owe their existence to enzyme intervention; but our using them, assimilating them, is made possible by these agents, to which we likewise are indebted for having such commodities as cotton, flax, wool, silk, leather, wood, etc.

Obviously, as all these articles are derived from the vegetable or animal kingdoms, the enzymes, whatever may be ascribed to them, must be found active in plants and animals.

That is true. All enzymes are produced from and perform most of their marvellous work within the *living cell.* Every attempt to produce an enzyme artificially in the laboratory has so far failed.

But after having followed for a long time and with dogged perseverance in their footsteps, chemical science has now succeeded in isolating enzymes from their living workshops, and has triumphantly compelled them to perform in the glass bottle the work that hitherto had been thought possible only in the living cell.

This flask contains the solution of an enzyme, "zymase," which has the faculty of splitting up sugar into alcohol and carbonic acid. A very few minutes after I now have added some zymase to the sugar solution contained in the second flask, an effervescence caused by the escaping carbonic acid gas will indicate that fermentation has set in, and before long all the sugar solution in the bottle will become dilute alcohol. Thus we see that alcoholic fermentation, which, in the great industries of alcohol, wine, and beer production, depends on the life and continuous propagation of yeast, is here performed away from any organic life by a merely chemical body, the zymase, which had been *isolated* from yeast.

Another striking example we have in an enzyme, catalase, isolated from the liver of the guinea-pig. One grain of this catalase thrown into a bottle containing about two pounds (14,000 grains) of hydrogen peroxide will in a short time split same up into water and into many cubic feet of oxygen.

Or I may mention urease, a urea-splitting enzyme, formed in the body of certain bacteria, and so powerful that the quantity of urea disintegrated per hour amounts to more than 1000 times the weight of their own bodies.

Also, in pepsin we have a case of extracellular enzyme action.

Bring one grain of a highly active pepsin preparation to act upon two pounds of finely-chopped meat, under proper conditions, and this meat, about 14,000 times the quantity of the enzyme employed, becomes liquefied and at the same time entirely converted into other bodies.

From the foregoing it must be clear to you that an astonishingly small amount of the enzyme will suffice for effecting transformation of the body on which it acts, the "substratum," and you may now readily surmise that the enzymes cannot themselves become a part of the new compounds formed.

In fact, if we could protect that one grain of pepsin, for example, from outward influences which tend to undermine its nature and constitution, we could continue and liquefy a thousand times 14,000 parts of meat with the same one part of pepsin, because it is just one of the extraordinary properties of the enzymes that they themselves remain unchanged and without in any way entering into the composition or into the change which they bring about.

In due desire to pay homage to the memory of a great mind, let me here read a passage from the writings of no less a personage than the Swedish chemist, Berzelius, who, far back in 1836, wrote:

"There seems to be a power which, by its mere presence and not by its chemical affinity, has the ability to awaken the affinities slumbering within the elements of bodies, so that in consequence the elements of a compound body may rearrange themselves in different manner; it seems to act after the manner of heat. I am going to use for this power the term 'catalytic power,' and for the decomposition which it brings about the name 'catalysis.'"

Berzelius thus defined such action as enzymes exert about fifty years ahead. The word "enzyme" was introduced by Professor Kühne, but not in the wider sense as it is applied to-day, because it was his belief that the enzymes could effect chemical operations only in the living cell. Now we know that the enzyme *is generated* in the living cell, but that its activity and efficiency are independent from the life process of such cell.

An enzyme is therefore a catalytic body in the sense as defined by Berzelius, but it is of organic origin, and is generated in the living cell, and also active independent of the life of the cell.

Catalytic bodies (enzymes are organic catalysts) of mineral nature hold sway in their different and widely fruitful domain. Wonderful results in this field are shown in our present way of making sulphuric acid by the contact (which means catalytic) process or in the Haber ammonia process, where the elements of ammonia, taken from air and water, are forced into union at high temperatures with the aid of catalysts under great pressure. At present Germany produces over 2,000,000 tons of the ammonia salts.

Here also belongs the hydrogenation of fats, wherein liquid oils are transformed into lard-like bodies for eating purposes or into stearin for candle-making, by causing them to combine with hydrogen gas through the catalytic intervention of metallic nickel.

The enzymes are remarkable in that their action depends on very specific conditions under which alone they can do their work, and that only on specific substances they can act. It has been ascertained that the enzymes act only on substances of definite structural nature, and the group of bodies thus acted upon is of a closely circumscribed character. Emil Fischer has aptly likened this relation of the enzymes to the substratum to a key and lock in which it fits: even a slight alteration of the key renders it useless for opening the lock.

Thus (*A*) in the process of digestion certain enzymes will dissolve and liquefy a certain class of material, which is left entirely untouched by others. Take the proteins contained in meat: they are liquefied (hydrolized) and converted in the stomach into bodies called peptones by the action of pepsin. To become assimilable by the body, however, the peptones have to be much more digested; in fact, they must be digested into all the bodies enumerated in Table I, to which I shall refer later.

If pepsin were left in contact with the peptones ever so long it would never accomplish the required degree of hydrolysis. To do this, an entirely different class of enzymes comes into play.

(*B*) Another characteristic of the enzymes is that for their best action they need specific temperature conditions. They are all destroyed by boiling temperatures, and even when acting at their optimum, which usually lies between 45° and 60° C., such a deviation as 5° frequently means a great variation in their activity.

(*C*) A point of paramount importance for their action consists in the proper reaction of the medium in which they work, whether acid, alkaline, or neutral. Pepsin, for instance, requires a decidedly acid reaction, such as is always found in the stomach. Amylase, which is contained in the saliva and which digests starch, becomes inoperative in the stomach by this very acid. Trypsin and erepsin, two enzymes contained in the intestines, on the other hand, need an alkaline medium for their work. Trypsin and erepsin continue and complete the protein digestion that was carried on by pepsin, in acid medium, to the peptone stage only.

(*D*) It has been fairly well established that the enzymes are of a colloidal nature. For instance, we can weaken the enzyme solution by violent shaking. They are readily absorbed by other colloids, and, similar to colloids, they can frequently be removed from their solutions by proper filtration through specially-prepared filters.

(*E*) Enzymes have never yet been prepared in chemically pure state, and even the best preparations must be considered very crude. As they originate from living cells, these preparations always have more or less mixed with them, or are " loaded " with, albuminous bodies. Whether the enzyme itself is of an albuminous nature, however, has not yet been definitely decided.

A truly incredible amount of labor and skill has been devoted to improve methods for preparing these valuable enzymes, and usually the substances have to go through a protracted and complicated series of processes. Solvents, like water, dilute salt solutions, very dilute acids, or alkalies, also dissolve most of the impurities which accompany the enzymes.

Glycerine, which does not dissolve albumen, is much in favor. For removing salts dialysis is used, but dialysis, as well as filtration, always tends to weaken the enzymatic efficiency, which further indicates the colloidal nature of the enzymes.

Alcohol and ether are much used in separating the enzymes from the impurities, and fractionated precipitation with ammonium sulphate is used for removing the ballast of albumen. The enzymes are mostly precipitated by heavy metals; they are absorbed by kaolin, talcum, charcoal, albumoses, precipitants, and especially by fibrin. Sometimes, when the resultant products contain sugars or other carbohydrates, these are removed by intense fermentations. I will not go further in this matter, but may say that, in spite of all attempts so far, it has not been possible to get actually pure enzymes in hand.

Likewise, technic for proving and estimating quantitatively enzymatic action is still in its infancy. We determine enzyme values only by the results which their action brings about. For instance, when we wish to establish the activity of a pepsin preparation we have a standard method of allowing the preparation to act for a specific time on egg-albumin and then figure out what quantity of egg-albumin has been dissolved by the action of the pepsin.

The best method of determining pepsin action is the one evolved by Fuld. For his method Fuld used the digestion of edestin, which is a globulin from hemp. This method is so sensitive that if we dissolve one part of an active enzyme pepsin preparation in a million parts of water we can still definitely determine its activity.

I now show you this edestin digestion by pepsin.

Similarly, in determining the activity of amylase, we allow it to act on a starch solution and then determine the quantity of sugars which are formed.

I cannot here further describe all methods which have been proposed to determine the activity of the various enzymes, as for each specific enzyme a special method had to be devised.

Frequently it is necessary to prevent the interference of bacterial action. The addition of toluol has proved to be particularly advantageous, as it prevents bacterial action and only in very slight degree interferes with enzyme action.

Ladies and gentlemen, I beg to confess that I feel a little nervous over having rushed in upon the task of offering you, by way of introduction to this brief lecture, a clear grasp of what enzymes are and what they do.

It would not do much good to recite here, in text-book fashion, even the main classifications and terms under which science now keeps this intricate subject-matter before its eye. I would rather propose, out of the innumerable bodies that are being built up by nature, with the help of enzymes, to select one, follow in the wake of its formation, and to try and pick up a little enzymatic knowledge as we go along.

Enzymes have ever to do with building up or breaking down of the materials whereof the bodies of animals and plants are made.

Processes, where new compounds are obtained by breaking down, are very prevalent. The fermentation industries, where sugar is split up into carbonic acid and alcohol, by the action of the ferment zymase, belong here. But this zymase action is only the last act in quite a series of breaking-down processes, or, as they are termed, " processes of dissimilation " through which beer is obtained from barley.

On the other hand, " processes of assimilation " through constructing or building up activity by enzymes are, of course, often paramount also. We need only to refer to the manner in which bodies like starch, albumin, and fat had been prepared before they were deposited in the barley corn, or as meat fibre or bodyfats in the animal tissue.

One highly noteworthy feature in enzyme activity must be seen in *reversibility of action*. The same enzyme, amylase, by which starch is converted into sugar, will, when occasion arises, form starch grains from dissolved sugar.

Lipase will, in the digestive tract, first segregate fats into fatty acids and glycerine, but later will again unite these constituents to the bodyfats deposited in the tissues.

The particular body on which I now wish to dwell, for the purpose of tracing enzyme action, is albumin, and no more important a subject could we choose.

Life is seated in albumin; the cell in its protoplasm teems with albumin, contains 50, 60, and 70 per cent. of albumin, and debarring the living organism from albumin means death.

Hitherto formation of albumin has been bound up with life processes in bodies of plants and animals. But a better equipment in enzymatic chemistry bids fair for the dawn of synthetic albumin made in chemical factories.

What that would mean becomes obvious when we realize under what conditions we now produce meat. For each 1000 pounds of albumin contained in 6000 pounds of pork we have to raise 25 pigs on about six acres of land. But in a building covering six acres probably as much albumin would be manufactured as on a ranch of 100,000 acres by the present methods.

But examples of similar cases we have close at hand.

In the year 1896 there were in India 1,583,000 acres used for growing indigo, and 8225 concerns were engaged in the making of indigo. By 1913 the number of concerns making indigo had dwindled down to 112. Now consider that the amount of synthetic indigo made in Germany in 1913 was six times the quantity of indigo produced in India in 1896, which means that the old methods of growing natural indigo would have required practically 10,000,000 acres of land to meet the market demands in 1913. This represents three times the acreage grown in potatoes in the United States, or, if you like, all the apple and other fruit orchards and tobacco land put together! And all this indigo was made by the Germans in practically one factory.

If this seems far fetched to you, I assure you it is more plausible than may appear. I show now in this bottle a sample of the so-called mineral yeast. It is to-day produced in Germany by the thousands of tons from ammonia and molasses. This particular sample contains 64 per cent. pure albumin.

What are the building stones used by the enzymes in the constructing of albumin?

Let us try and get an answer to the following very simple proposition:

If, in the case of our own body, the albuminous parts, such as muscle, blood-serum, etc., had all been formed from the food we have eaten (which to a very large part consists of albumin), then an exact knowledge of what became of this food-albumin in the digestive process and of how the digestion products were used up in forming our muscle, etc.—such exact knowledge would certainly enlighten us on the subject of building stones used in forming the albuminous parts of the human body.

It is precisely on this simple line of reasoning that those penetrating minds which have cleared up the laws of albumin formation have set in with their relentless work and carried it to success.

The first changing of food-albumin to simpler bodies is brought about by an enzyme produced in oblong glands imbedded in the mucous membrane which forms the interlining of the stomach. On leaving the glands the enzyme is incomplete, inactive, a "zymogen." Zymogens are, so to speak, rudimentary enzymes, which must come in contact with an "activator" to become real enzymes. Our zymogen enters into intimate combination with hydrochloric acid, of which the stomach juice contains 0.2 to 0.5 per cent.

The enzyme, pepsin, becomes activated thereby and depends always, as I already pointed out, for its action on a decided acid reaction of its medium.

The albumoses, proteoses, and peptones resulting from pepsin action are already water-soluble.

These albumoses, peptones, etc., now in solution, are not by any means completely digested; they are not fit to be assimilated by the liver, the blood, etc. They must be broken up into bodies, such as are enumerated in Table I. Therefore another body enzyme, of a different specificity, trypsin, comes into play. This trypsin, by virtue of its specific adaptation, can act upon these substances and further hydrolize them.

Trypsin, originating from the pancreas gland, is being injected into the digestion mixture in the duodenum. The activity of trypsin would become entirely stopped by the presence of even 0.1 per cent. of hydrochloric acid, because it requires an alkaline medium, and has been found to work best when the alkalinity corresponds to about 0.75 per cent. of sodium carbonate.

There is still another enzyme, exclusively found in the enteric channel, erepsin, specific in a similar way as trypsin, only it is more thorough and brings the cleavage down to the last but one member of our list—to glycocoll.

Now remember what we learned about reversibility in action of enzymes. I told you that the same enzyme, amylase, by which starch is converted into sugar, would, if occasion arises, form starch grains from dissolved sugar. Precisely so here, we find that the albumins disintegrated by the enzymes just mentioned must by the same enzymes be reconstructed.

First (in the gut), to body albumin.

It is most remarkable that this body albumin is specific for the animal in which it takes rise, and even the peptones, after the reconstruction, in no way resemble the original sources.

The body albumin aforesaid has to be broken down again and reconstructed before it can become organ albumin. Also, here we find specific enzymes active; the liver albumin differs from the one found in the kidneys or blood-corpuscles, etc.

In this manner the enzymes are active backward and forward in the body in the albumin construction work. For instance, pepsin is found and is active in this sense in the blood and in the muscles.

The work done on these lines in the body is carried on by a number of specific enzymes, more than twenty in all.

We owe principally to the work of Prof. Emil Fischer, of Berlin, the knowledge basic to our present insight into the constitution of albumin. His first great achievement was the separation of all these many bodies into definite chemical individuals. The task was almost insuperable, but he ultimately succeeded by combining the mixtures of the many digestion products into salts or esters and then inventing a vacuum distillation process through which he could separate the esters, and thus he isolated the pure individual albumin building stones. Then he and his co-workers, especially Professor Abderhalden, of Halle, succeeded in preparing a large number of these identical bodies outside the body, in the chemical laboratory, by purely chemical means, and it has been established that a great many of these artificial albumin bodies can be digested and reconstructed by body enzymes the same as natural ones.

Of these synthetic laboratory products, the "polypeptides," Prof. E. Fisher says:

" From all observations so far made there is an unmistakable similarity between the artificial peptides and the natural peptones. This holds particularly for those synthetic products which contain various amino-acids, and which I shall in future designate as 'mixed polypeptides.' The ordinary reactions of peptones—biuret coloration, precipitation with phosphotungstic acid, hydrolysis with trypsin—hold also for the complex products, and are even more characteristic of their amides. It is indeed true that there are differences in physical properties; thus certain of the artificial polypeptides are comparatively difficultly soluble in water. But this difference loses in significance from the fact that the mixed forms, particularly the optically active combinations, are much more soluble in cold water.

" We should further expect that the introduction of the diamino- and oxyamino-acids into the molecule would further increase the solubility in water and diminish the tendency to crystallization.

" Taken altogether, I am inclined to believe that the acquisition of the artificial polypeptides is the most important step toward the synthesis of the peptones."

Following is a list of individual bodies obtained in albumin cleavage:

Table I.

PROTEOSES ALBUMOSES, PEPTONES.

L. Tryptophane.
L. Histidine.
L. Proline.
L. Tyrosine.
L. Phenylalanine.
D. Arginine.
D. Ornithine.
D. Lysine.
L. Asparaginic acid.

L. Cystine.
D. Isoleucine.
L. Leucine.
D. Valine.
Alanine.
Glycocoll.
Urea.
———
Ammonia.

The five simpler forms from D. isoleucine to glycocoll are the simple amino-acids.

It is probable that the cleavage products become united in and to the albumins in amid-fashion.

The lowest member of the list is urea. Urea is a waste product from the body; it is detached through the kidneys and bladder.

Still lower, below the line, is ammonia.

The animal body is not in the habit of producing this simplest form of combined nitrogen, ammonia; its lowest waste product is urea. However, some plants do; we have examples of certain fungi which secrete ammonia as a waste product. Ammonia escapes from bacterial and fungi cultures often in great quantities.

Likewise, the animal body is entirely incapable of utilizing ammonia for the building up of albumin.

That is reserved exclusively for the plants, which are kept provided with mineral nitrogen (ammonia, nitrates) through their roots.

How do plants build up albumin from mineral nitrogen and carbohydrates, or, as we heard in the case of mineral yeast, from ammonia and sugar?

First, we know that the great function of uniting the elements of water and carbon into starch is performed in the plants by the process of assimilation, through the action of the sun-rays. After this operation, which probably depends on catalytic action, starch grains are observed to appear in the cell. These starch grains are embedded in the protoplasm of the cell in the green leaves.

But starch grains are also found in places where the conditions for their origination absolutely do not exist. A question arises—and it is intimately connected with the activity of the enzymes: How do these starch grains get translocated from the place of their first making or appearing to the various other places in the body of the plant where they are found? They surely could not have pierced the cell walls; that idea is altogether untenable.

One observation about starch grains was early made: namely, that they disappear from the chlorophyll mass of the green plants in which they are embedded when the plants are placed in the dark. Under these conditions, starch grains remain in the chlorophyll-bearing cell only very shortly: they are found to disappear very soon after the conditions for creating new starch grains; that is, the action of light has been removed.

What has become of the starch?

We have in iodine an extremely sensitive reagent for detecting the presence of starch; it is turned deeply blue by iodine. In the part of the cell which is outside the protoplasmic mass starch had never been detected, therefore it could not even penetrate from the protoplasmic mass into the outer layers, let alone wander to remote parts of the plant. Finally, it was found that the cell-juice has the remarkable faculty of dissolving starch and at the same time entirely changing its chemical nature and converting the starch into a sugar.

The change is an enzymatic one, by the action of an enzyme, named diastase, or amylase.

This enzyme amylase is provided by nature wherever the breaking up of starch in this sense has to take place. We find it, for instance, in the saliva where it attacks the starch content of our bread and food; further on, in the stomach, its activity is arrested through the acid reaction which, as I told you, must always prevail where the pepsin, the first albumin digester, has free sway. But later on, in the intestines, the amylase is again found, and it there completes functions of starch resolving quite similar to those we have observed in the protoplasm of the green leaves.

I shall now demonstrate to you here the conversion of starch *in vitro;* show with Fehling's solution that Cu reduction only now sets in.

The great starch containers known to us are tubers, like potatoes, or the grains, seeds, etc. When converting these starch reserves for the use of the young plants, the enzyme amylase, or diastase, is developed from the very embryo of the young plant.

It bears on our subject of fermentation that practically all studies of these enzymes have been conducted with the enzyme amylase contained in malt extracts, because malt is nothing but barley where incipient growth had been brought about for the very purpose of developing this and also other enzymes.

The sugar or transportable carbohydrate formed from the starch can now, by its soluble nature, penetrate through all cell walls and enter into the protoplasm itself. It is worked up into starch again in many cases where a temporary accumulation of starch is required; and then in that case the iodine reaction is fully restored. It is used as a building stone for making cellulose walls and the whole frame of the plant, bark, leaves, and roots.

Now, for the purpose of our discussion, take it for granted that sugar is found everywhere in the body of the plant—in the stalks, in the leaves, in the roots, in all tissues; and let us now try to understand how this sugar, in conjunction with ammonia salts, may form albumin.

The first conjectures as to how the plants, these original first-hand albumin constructors from the purely mineral salts and sugar (carbohydrates), perform this work which, as I said, could never be brought about in the animal body, was based upon observations of the movements of foods in the young plants. We know that all young plants are provided with a stock of albumin in the seeds; in the course of development of the plant these albumins are acted upon by the enzymes and converted into peptones, albumoses, peptides, and amino-acids in a way entirely analogous to the digestion of albumin in the animal body.

In the mobilization of albumin in the young plant it was early observed that two intermediary organic nitrogen bodies, asparagine and glutamine, were frequently stored up, and it has since been established that they play the highly important rôle of being stored-up building materials for albumin throughout plant life.

The asparagine and glutamine are, as it were, organic ammonias or near-ammonias, somewhat similar to the waste material, urea, which, as we said before, is thrown out by our body. Plants, however, husband their organic ammonia in the form of asparagine and glutamine, and accumulate it for future disposal.

It is highly significant that asparagine and glutamine are soluble, transportable, and as such can travel to where they are needed in the plant.

When it was first shown that, by feeding ammonia salts to young plants, the amount of asparagine and glutamine became increased, we had the first inkling of how the mineral ammonia might be worked in with the organic building material for producing albumin.

Now ammonia or nitrates, by reason of their composition, would not for any length of time alone account for a building up of albumin if the elements of starch or sugar were not also drawn upon. The significant experiments by Saleski in this connection are instructive.

Saleski placed leaves of the sunflower on top of a Knoop nutrient solution (the one used by Professor Knoop, of Leipzig, in his extensive work of cultivating plants in artificial food solutions) to which he had added 4 per cent. of levulose.

The constituents of the Knoop solution are all of a mineral nature, as you may see in the following table:

Koop's Solution in one Litre:

	Grammes
Calcium nitrate	1.30
Potassium nitrate	.33
Prim. potassium phosphate	.33
Potassium chloride	.16
Magnesium sulphate	.33
Ferric chloride	trace.

The increase of albumin which resulted from this experiment must have been taken by the leaves from this stock of nitrates and sugar.

The leaves are the chief laboratories in which albumin is synthesized from nitrogenous substances, but the work also continuously goes on in most other parts, the surface tissues, the roots, etc.

As to what actually takes place in this wonderful process, let me say that probably all mineral nitrogen must be in the form of ammonia, into which nitrates have first to be converted; then follows formation of asparagine and glutamine.

These two important building stones for vegetable albumin are invariably formed, and to the exclusion of albumin production, when young plants are grown in the dark. But as soon as light is admitted, and thereby starch (and sugar) produced, real albumin is formed, showing that carbohydrates are indispensable.

Thus in the formation of albumin by the plants two main nitrogen-adjustments become disclosed:

1. The rich reserve bodies, asparagine and glutamine (which contain 20 to 21 per cent. nitrogen) become levelled down to albumin (containing 16 per cent. nitrogen) through the entrance of the nitrogen-free carbohydrates (sugar).

2. These reserve bodies (asparagine and glutamine) become synthesized from ammonia by its combining with small amounts of the ever-present amino-acids (which are poor in nitrogen, containing only about 10 per cent.).

Albumin contains much less oxygen than starch or sugar, and a reduction process during the formation of albumin takes place through the intervention of an enzyme, " reductase."

Of the vegetable peptases and amidases that came into play, and especially on enzymatic processes during the first interaction of asparagine and sugar, our knowledge is very meagre.

This extremely brief sketch on the enzymatic albumin formation must suffice; it gives prominence to the following points:

1. Only plants can utilize mineral nitrogen for the building up of albumin. They combine this nitrogen with carbohydrates (sugar), and, as they likewise form the latter from mineral substances (carbonic acid and water), therefore the plants construct albumin from inorganic matter through enzymatic and catalytic activities.

2. Plants do not, like animals, discharge the waste nitrogen in the form of urea, but they husband and deposit such near-ammonia as asparagine and glutamine in places where albumin increase has usually been noted.

3. The building stones for constructing albumen are joined together, the near-ammonias and carbohydrates in plant life, or amino-acids in the animal body, to the higher forms of albumoses or real albumins, by the intervention of enzymes either identical or similar to those which cause the work of dissimilation or breaking up into lower or simpler forms.

In addition to the wandering of the starch and sugar and asparagine, we have now in the plant a wandering of albumin, which has to furnish the elements for the protoplasm and is everywhere playing a most important part in the development and building up of the body of the plant in seeds and fruits before ripening albumoses are found.

When the plant is fully developed, the movement of all these materials, moved by amylolytic, peptic, and other enzymes, takes a different course. The starch, the albumin, and the fat then produced are transported into the seed, into the tubers, where they act as reserve food material for the young plant.

In the case of plants whose life-cycle is not completed in one season, in perennial plants, a station of rest exists for the winter, at least in the temperate climes, and there in addition reserve food containers in the younger wooded or vegetative parts are filled with starch, albumin, etc., to serve as first food for the development of the young leaves the following spring.

Besides the starch-cleaving and the proteolytic enzymes, there are a large number of other enzymes active in the life of the plant and animal.

Thus "maltase" is indispensable after the conversion of starch into sugar by amylase. The amylase is only able to form maltose as a first step, and this maltose, though transportable, is not fit for being used in many of the cases where the sugar is to be applied in constructive work. Maltase, therefore, which changes the maltose into dextrose, is frequently found accompanying amylase.

Likewise, in our body, it is present in the saliva; always in the gut, especially in the small intestines, in the blood, in the serum and in the pancreatic secretions.

Another important enzyme is invertase, which has the faculty of converting cane-sugar into fructose. It is found in the leaves, roots, stalks, etc., also almost throughout the animal body. The saliva does not contain in this invertase, but it is present in the stomach juice and the pancreas.

Interesting experiments have shown that by injecting cane-sugar into blood this invertase, this enzyme by which cane-sugar can be resolved into absorbable sugar, is being engendered. However, here, as is usual in enzymatic problems, several different invertases exist to meet special substrata conditions.

Without entering further into the great field of these various enzymes, I will say a word about the lipases—the fat enzymes.

The important question, how the fats in the seeds are being converted into food for the young plant, has not been elucidated until recently. A special class of enzymes, the lipases, come into play in the splitting up of the fats, as a first step, into glycerine and fatty acids.

Particularly rich in this lipase is the castor-bean seed, and Cohnstein and his co-workers established, in 1902, methods of utilizing their castor-bean enzyme for industrial purposes by decomposition of fatty oils into fatty acids and glycerine.

The fats are produced in the plant from starch and sugar by a reduction process similar to the utilization of these carbohydrates in the formation of albumin. Probably the breathing of the plants through their leaves plays an important rôle with this fat-forming function of the enzymes.

Of course, many are the functions of the various classes of lipases that exist and are operative in the animal body. They are found in the stomach, in the pancreas, in the animal tissue, and in the blood.

The much-debated question as to how the fats are digested is now pretty well solved on the basis of lipase action throughout. While formerly it was believed that fats were merely finely emulsified and in the form of the very fine emulsions could wander through the membranes of the gut, etc., it has now been proved that lipase in various stages splits up the fats into glycerine and fatty acids which, as such, are then, by a reversible action of the lipase, united and constructed again into real fats.

I will here insert a list of the more important classes of enzymes:

TABLE II.

Animal Proteases.

Pepsin, the principal enzyme of the stomach, where it acts in presence of hydrochloric acid, acts on all natural albumins (proteins), degrading them mainly to the stage of albumoses and peptones); also has functions in gut, liver, blood, etc.

Trypsin likewise resolves natural proteins, but beyond the peptone stage, and even to amino-acids. Found in the pancreatic juice, works in the gut in alkaline medium. Animals can live and digest with stomach extirpated, but die when pancreas is removed. Thus trypsin supplements and may replace pepsin functions. Trypsin becomes activated by the enterokinase.

Erepsin, in the enteric juice, digests peptones to amino-acids.

Chymase, an enzyme in rennet, cleaves casein of milk to paracasein, which then forms the curdle in combination with calcium salts.

Arginase produces urea (and orinthine) from arginin. Prepared from the liver.

Urease, decomposes urea into ammonia and carbonic acid. Produced by bacteria; also found in soya beans.

Amidases split guanin and adenin into ammonia and hydroxic acids.

Nucleases make available the phosphorus compounds from our food. Those compounds become insoluble in and are discharged from the stomach as nucleo-proteins. In the gut the erepsin splits off the protein, which is digested in the ordinary way, while the nuclease, from the remaining nucleic acid, forms and sets free the phosphoric acid.

Nucleases perform similar functions in the vegetable system.

Vegetable Proteases.

Proteinases in plants correspond to the pepsin in the animal body, and break down vegetable albumins as far as albumoses and peptones.

Tryptases correspond to trypsin in the animal body. Proteinases and tryptases are contained in bromelin found in pineapple. A similar enzyme is papain contained in the fruit, leaves, and stems of the papaya tree.

Peptases (erepsases) break down vegetable peptones to amino-acids.

Endotryptase, the powerful proteolytic enzyme of yeast, resolves all the proteins to amino-acids.

Amylases.

Abundantly in leaves, roots, seeds, etc. (oats, barley, corn, potatoes), where starch is hydrolized by them to maltose. In saliva, enteric juice, liver, blood, the body amylases perform similar functions.

Di-Saccharases.

Maltase transforms maltose to dextrose.

Invertase splits saccharose into invert-sugar (fructose).

Lactase breaks up milk-sugar into galactose and dextrose.

Emulsine decomposes amygdaline.

Cellulase and *cytase* attack cellulose and make hemicelluloses available for food.

Zymases

cause splitting up of sugars in alcoholic fermentations.

Phytase,

omnipresent in plants, splits phytine, an important phosphorus-carrying reserve-body, and thereby makes available the phosphorus for building up nucleines and lipoides.

Oxidases

perform activating functions, making possible the important oxidation process within the cell.

Reductases,

in unboiled milk, which therefore discolor methylene-blue, probably coöperate in formation of fats from starch.

Catalases

decompose hydrogen peroxide to water and oxygen. In the blood catalase detaches from the red corpuscles the stored oxygen, which then becomes available (after activation by oxidase) for Oxidation-process within cell.

Lipases.

SPLIT FATS.

Animal lipases act in stomach juice, the enteric juice, in blood, and in the tissues.

The fats are split by lipase and made soluble in water through the agency of bile. Later, by synthetic action of the enteric lipase, the components again unite and actual fats are deposited.

Vegetable or Phyto-Lipases make available the large deposits of fats stored in oil seeds, nuts, etc., for use by the young plant.

Thrombase,

the fibrin-forming enzyme, causing coagulation of the blood, becomes active by admission of air and in presence of small quantities of lime salts. Fresh blood easily flows from the veins, unless the wound is stopped by the fibrin fibres.

The outline given on the nature and activities of enzymes has sufficiently paved the way to discuss their relationship to the special field of the fermentation industries.

The term " fermentation," as a rule, arouses in the layman's mind a vision of bubbling or something boiling—something in motion with evolution of gas. While this holds good in numerous cases, it is by no means a characteristic criterion, and many fermentations exist where none of the resulting bodies come off in the form of gas.

The field of fermentation is very extensive, and I shall confine myself mainly to discuss the enzyme actions in brewing. A good understanding of the many enzymatic processes involved in the production of beer will form an acceptable nucleus around which to acquire knowledge on enzyme actions in other branches of the fermentation industry, such as the production of ethyl alcohol, acetic, lactic, and butyric acids.

The principal raw material in brewing is barley. The ripe barley really represents a well-provisioned storehouse for the young plant, holding starch, sugar, albumins, organic phosphorous compounds, etc., in their proper places, and it is one of the tasks of the brewer that these materials deposited in the grain are, during the malting and mashing process, once more made soluble.

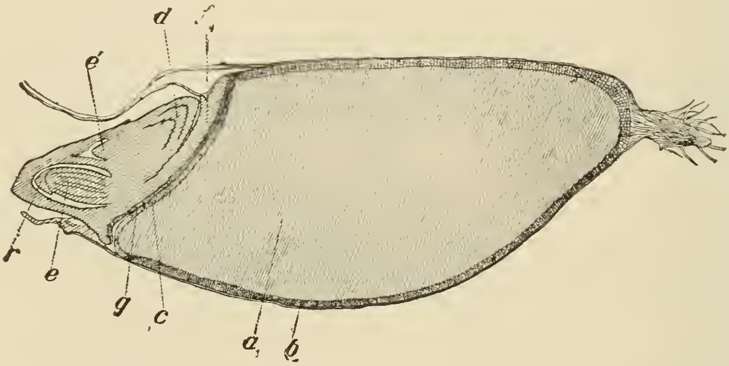
This transformation is accomplished by properly directing the action of the same enzymes through whose instrumentality these substances had originally been transformed, transported, and stored while on the field.

We may well realize, then, the importance of favorable conditions for their original action during growth and ripening to assure a barley which will be a good brewing material.

I call attention here to the importance of soil conditions, to the mode of fertilizing, and the influence of climate on the quality of the barley.

Wet seasons are very damaging, and continuous dry weather for, say, four to six weeks previous to maturing is especially fatal for those enzymatic functions that are accountable for the proper filling of the endosperm and the aleurone layer. Even after harvesting, due time must be allowed to carry ripening operations to a finish, which is usually attained by keeping the barley stored (unthrashed) for some time. Suffice it to say that, in view of quality considerations, good brewing barley frequently commands prices that are 25 per cent. higher than those for other barleys.

FIG. 1.

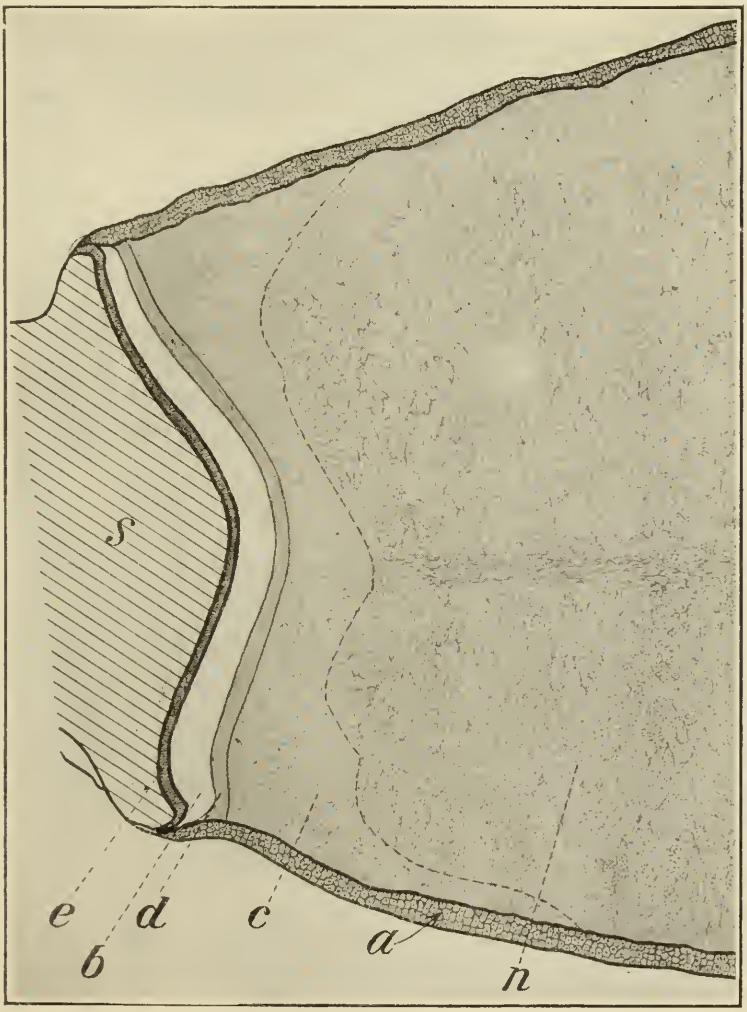


Longitudinal (dorsi-ventral) section of a mature barley grain. *a*, starch endosperm; *b*, aleurone layer; *c*, area of starch endosperm, adjacent to the scutellum, representing the initial stage of the corrosion of the endosperm. This took place at the close of the ripening of the grain. *d-r*, the embryo; *d*, plumule with investing sheath; *e*, primary, and *e′*, secondary, radicles; *f*, scutellum, the surface next to the endosperm covered with the epithelial layer (*g*); *r*, root cap of primary radicle.

In showing you herewith lantern slides of barley, also sections through a barley kernel, I beg to state that I am indebted to the Department of Agriculture, Bureau of Plant Industry, for kind assistance in this matter.

More especially I wish to say that a professional paper by Messrs. Albert Mann, Plant Morphologist, and H. V. Harlan, Agronomist in Charge of Barley Investigations, and entitled "Morphology of the Barley Grain with Reference to its Enzyme-secreting Areas," published April 13, 1915, has been of very considerable value to me through the elucidation of the subject by their research.

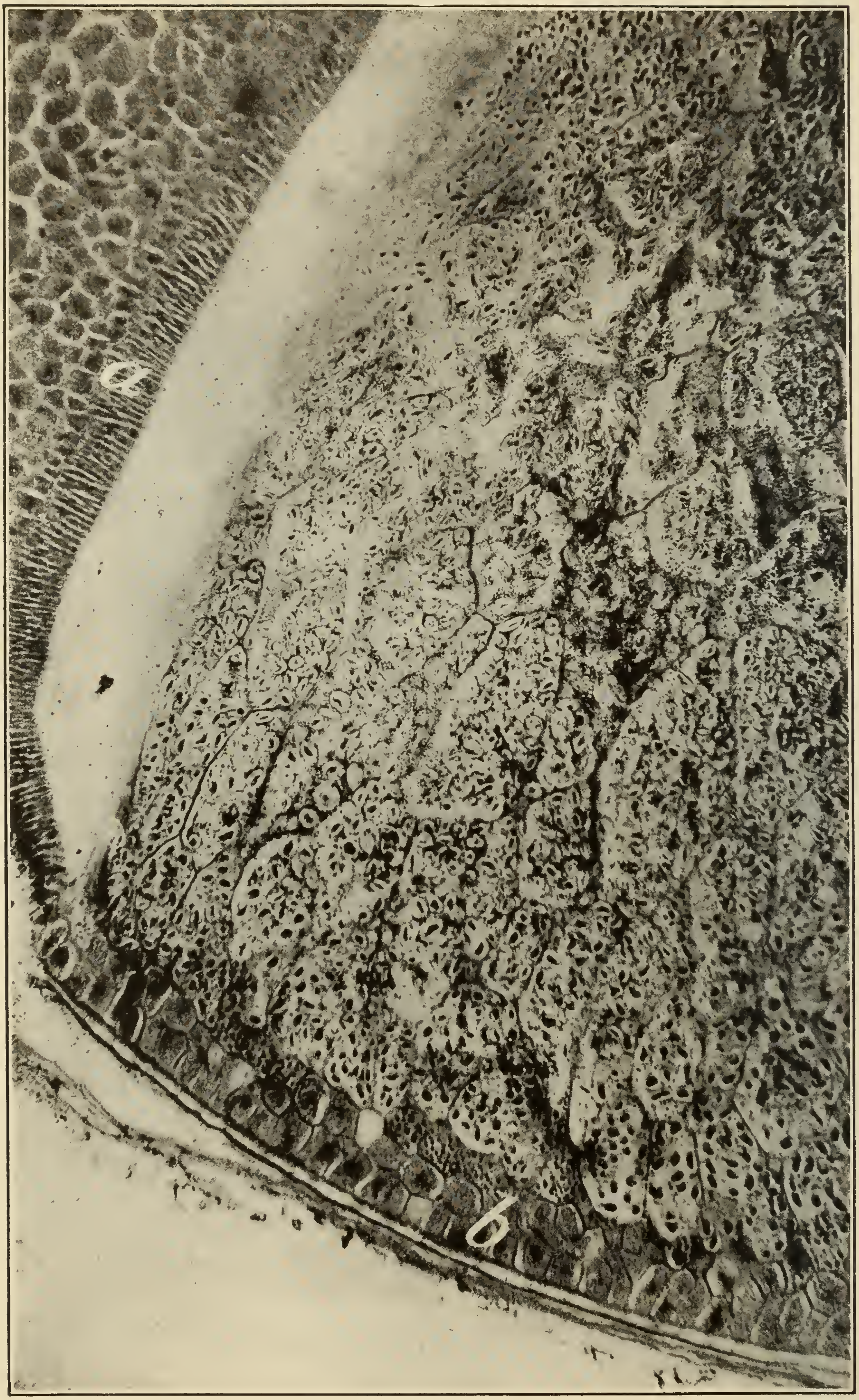
FIG. 2.



Longitudinal section of barley grain, showing the stage of endosperm conversion at the end of the second day of germination. The starch endosperm is being broken down in the dense areas directly in front of the epithelial layer (*e*) of the scutellum (*s*), and more rapidly in the less dense areas adjacent to the aleurone layer (*a*). *b*, clear fluid area produced during germination; *c*, corroded area of starch endosperm; *n*, normal starch endosperm not yet attacked.

Two main parts are at once apparent: The starch-bearing endosperm, Fig. 1, *a*, and the embryo, *d–r*.

FIG. 3.



Photomicrograph of a part of the scutellum and endosperm of a germinating barley grain. The initial stage of germination is shown. Enzymatic action has begun in front of the epithelial layer (*a*), but not next the aleurone (*b*).

The embryo amounts in weight to about 3 per cent. of the barley corn. You see here, enclosed in a sheath of cellular tissue, the *plumule* (*d*) and the *radicle* (*c, ć*), the two principal parts of the still rudimentary future plant. The tissue on the side toward the endosperm, which appears somewhat raised, like a small shield, is called the *scutellum* (*f*). It serves as an intermediary organ for absorbing food, which has to pass through it on its way from the endosperm to the embryo.

Between the scutellum and the endosperm there is, however, one other cell-layer, the very important epithelial layer (*g*). These cells are elongated in form and stand at right angles to the scutellum as well as to the opposite endosperm.

It is now considered probable that the epithelium produces and secretes the enzymes, which from there make their way into the endosperm, where they liquefy and make available the stored-up reserve materials which the embryo needs for respiration and growth.

The whole endosperm is surrounded by, and enclosed in, the aleurone layer (*b*). When the kernel grows the aleurone layer consists in the beginning of a single layer of strong cubical cells, which grow to three as the endosperm-mass develops. This aleurone layer, which contains large quantities of histological albumin, is not affected in malting, and is found intact even in the residuary grains from the brewer's mash-tub.

Figs. 2 and 3 show additional detail; Fig. 4, a whole barley grain from the outside.

Another class of albumin is found in large amounts in the layer beneath the aleurone layer, and this albumin, which does undergo enzymatic changes during the malting and mashing operations, is called the physiological or reserve albumin.

The starch-cells constitute the bulk of the endosperm. Most of them show much compression, and their centres are distorted, except the cells bordering on the aleurone layer, which are the last in the endosperm tissue to fill with starch and are more spongy and not so densely packed.

The epithelium cells, from which, as we have stated, probably emanate the various enzymes, cytase, amylase, protease, phytase, etc., will during germination grow to four times their original

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NOTE.—The illustrations, Figs. 1 to 4, are from Mann and Harlan's "Morphology of the Barley Grain," Bul. 183, U. S. Department of Agriculture.

length and, according to Mann and Harlan, also show marked differences in their protoplasmic contents. At times they appear to be heavily charged at the ends; then these plasmatic lumps again disappear and are periodically formed anew and disappear again.

I shall now briefly describe the principal practical brewery operations, and refer more especially to the enzyme actions taking place.

MALTING PROCESS.

The barley is steeped in water for about 48 hours, during which time it absorbs 40 to 50 per cent. of its own weight of water. Then the steeped barley is put in heaps several feet high. Before long the process of germination begins and a rise of temperature sets in.

As germination progresses, the heap is continually spread out on the floors and turned over from time to time to provide proper ventilation, and the germination is allowed to proceed until the acrospire (the young plant) has grown to about three-fourths of the full length of the kernel.

This is the old process and is called "floor malting."

In the newer process, called "pneumatic malting," the germination of the barley is done either in drums or in compartments (Saladin process) where the germinating barley is loosened and turned over by machinery and temperatures and moisture content of the air are automatically regulated.

With either method the germination process requires approximately one week.

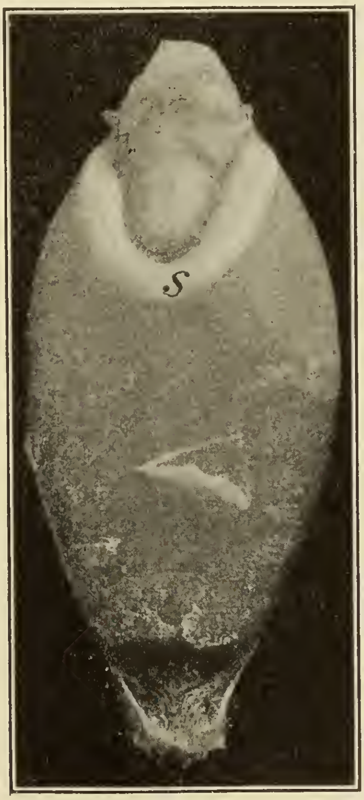
I herewith show you samples of growing barley in different stages of the process:

A. Barley.
B. After three days' germination.
C. After seven days' germination.
D. Finished malt.

Let us now consider what changes have taken place in the barley during malting. Physiological activities began from the first moment of its contact with the steeping water. Respiration was at first sustained by the small amount of sugar which the barley contained and which became dissolved through steeping. The soluble food material was soon used up and the embryo needed further food for its development; it needed carbohydrates, nitrogenous and mineral substances, which all had to be provided in water-soluble and diffusible form.

As we know, the reserve materials contained in the endosperm, however, are practically all in the form of insoluble compounds, starch, albumin, and organic phosphor compounds. To make these available, the whole machinery of enzyme secretion is set into motion by the embryo, and our barley corn becomes converted from a storehouse into an intricate laboratory.

FIG. 4.



A high-grade barley grain with the glumes removed to show the embryo with its collar-like scutellum (*s*). The inner envelopes have been removed from the upper part of the grain.

To do this work of making available and degrading the reserve material, the embryo secretes a number of enzymes which accomplish this task with the greatest ease. Among those enzymes to do this work we may mention oxidase, cytase, amylase, protease, and phytase.

The formation of amylase during germination has been made a particular subject of study, and I refer here to the work of Brown and Morris, Gruess, and Mann and Harlan.

Mann and Harlan showed that the first change observable during germination begins in the narrow layer of empty cells between the epithelial layer and the endosperm proper. The process soon affects the starch-bearing cells of the endosperm and gradually permeates the whole grain. Those layers of starch which are beneath the aleurone wall are first attacked, and this is responsible for the former view that the amylase was secreted from the aleurone layer. The real reason for this phenomenon, however, is the fact already mentioned, that the peripheral starch-cells are younger and less densely filled with starch, therefore more readily succumb to the enzymatic action.

The conversion of starch could not have been performed unless the cytase, a special enzyme, had previously acted upon the cell walls of the starch-cells.

By action of the cytase, these cell walls swell, become pitted and corroded; they, however, never entirely disappear.

The presence of two proteases has been established, and they attack and partly dissolve and degrade the physiological albumin.

The enzyme phytase performs the work of mineralizing organic phosphorus compounds, which, as we shall presently see, are also of greatest importance during the fermenting phase, for it has been established that the yeast enzyme, zymase, which performs the real fermentation work, can only do so in the presence and in combination with the alkaline phosphates.

Due to the action of these various enzymes, the whole physical condition of the barley is also completely changed; its original glassiness disappears, and the endosperm becomes floury and friable and in a condition to be readily acted upon at a later stage (that is, during the mashing process), which we will discuss presently.

During this germination, which usually lasts about a week, large amounts of carbonic acid are given off.

The oxygen, in order to become available for the breathing, must be activated. This is performed through the intervention of a special class of enzymes belonging to the group of the oxidases. If sufficient air is not available, the young plant will for a while provide its oxygen by decomposing its own substance; but the products that arise from such intermolecular breathing are poisonous and finally kill the young plant itself.

(To be concluded in June issue.)

CHEMISTRY AND AMERICAN INDUSTRY.*

BY

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THE fact that chemistry is the real basis of human industry has been better advertised during the past two years and is now more fully understood by the general public than ever before in the history of the human race. Long before the word "chemistry" existed, prehistoric man began to practise the art, when he discovered, some time in the dim past, that the fires he built against the walls of cliff and cave changed the nature of the earthy materials with which he was familiar. Ceramics and metallurgy are the oldest of human industries, and none are more dependent upon obscure chemical actions and reactions. Although ancient as a practised art, chemistry as a science is no older than our own Declaration of Independence, and, indeed, may be said to have germinated from its seed in the bloody soil and under the murky clouds of war and revolution. Lavoisier, the great Frenchman, the father of the modern science of chemistry, was guillotined by the angry mob at the time of the Terror, but, like John Brown's, his soul goes marching on. It is curious that it should be reserved for this second time of Terror to give a new impetus to this most basic of all the arts and sciences. If war was destined to bring all evil and no good in its train, optimism would be impossible and race suicide excusable.

If American industry is to learn and benefit from the lessons of the past three years, it is necessary that the American people should realize more keenly and with a more active interest some of the facts that this paper will attempt to set forth. Either directly or indirectly, chemistry as applied to industry affects the conditions and well-being of every American home. The clothes we wear, the food we eat, the utensils we handle and prepare it with, the materials of construction with which we are housed or transported from place to place, the medicines which we depend upon in the struggle with disease and death, are all, in one way or another, dependent upon strictly chemical industries. It is chemistry that has made it possible to produce iron and steel on the enormous tonnage scale that makes modern civilization possible. It is chemistry that teaches us to make from ill-smelling, viscid coal-tar, the by-product of the gas and coke industry, thousands of beautiful colors and dyes, medicinals, and high explosives. The red silk parasol of a summer beach and the red wound of war have a common origin in that black, sticky mass. It is chemistry that has developed that wonderful structural material, Portland cement, that enables man to mould his building stone in the place he wants it so that in a few hours it attains the same condition of solidity and durability possessed by rock which Nature laid down and solidified in the course of geological epochs. Truly man takes upon himself the attributes of a creator when he learns to properly apply the principles and science of chemistry to the materials which surround him.

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* Presented at the stated meeting of the Institute held Wednesday, March 21, 1917.

Our country, with its vast natural resources in coal, ores, and lumber, and with its extraordinarily diversified products of agriculture, has had special need to apply science to industry. Much has been done, but at best, except possibly in some exclusive lines, we have not heretofore kept pace with Europe in the application of chemistry to industry. It will do no harm and may do good to state very clearly that the apathy and careless ignorance of our people in regard to applied science in general have constituted a great hindrance to our progress along certain most important lines. George Washington, with the wisdom which was his, foresaw this national tendency, and his state papers constantly urged upon the Congress and the people that state of preparedness which depends upon the application of science to the arts of peace and war. Nevertheless, the great European war, with its consequent embargoes, found us terribly deficient in any preparation for an event that a wise government and people might have foreseen and anticipated as at least a dangerous possibility. And so for a long time after the outbreak of war there was a great scurrying about in our industrial ant hill, and great consternation over the question as to what some of our important enterprises were going to do without supplies of certain essential raw materials necessary to the arts, industries, and to the national defense. And now, as these words are written, with the world war threatening to engulf us also, great mills and factories in many sections of the country are shutting down and banking their fires for the lack of cars to move fuel to the furnaces. It would seem that a wise government should recognize that in order to be an efficient people in peace or war the wheels of industry must be kept moving. The much-debated question of belated battleships that should have been building years ago is serious enough, but crippled industry is far more ominous, and its relief is worthy of the study and the helpful coöperation of government. The attitude of the great mass of the American people as expressed through its government has, however, for years past been one of passive indifference when it has not been one of active hostility, not only to the great chemical industries but to the railways which feed them and distribute their products.

The past two years have seen a better appreciation by the layman and the press as to the place chemistry really occupies in the national life, but even now people who are not technically trained do not realize that certain minor constituents which enter into the production of the necessities of life and national defense are quite as important factors in our political and economic salvation as the main-line raw materials. With all the wood, wool, cotton, coal, copper, and iron in the world in our possession, our mills and factories would stand idle if certain needed chemicals, whose very names are often unfamiliar to the man in the street, were unobtainable. Dr. George D. Rosengarten, a member of this Institute, in a presidential address before the American Institute of Chemical Engineers, has strikingly pointed out that had it not been for the discovery of sulphur in Louisiana and the economical method of mining it, devised by a famous chemist, in 1891, the balance of trade would not now be on our side to-day, and untold millions of dollars that have come to this country would have stayed at home or have gone elsewhere. How many people realize that the quantity of sulphuric acid consumed by a nation is a measure of its industry, that a large part of the great iron and steel mills would have to shut down for lack of it, while not a pound of powder to serve the guns could be made without this corrosive liquid?

As an interesting instance of the influence of more or less obscure minerals and chemicals on the destiny of nations, I wish to refer to a speech before the Parliament made by the British Minister of Munitions, the Rt. Hon. Edwin Montague, on August 15, 1916. In describing one morning's work, he recites how he began his day completing arrangements for the transport from near the Arctic Circle to a neutral country of a mineral, the name of which was unknown to him, but which he understood was the limiting factor in the output of certain indispensable munitions. He next took up the question as to whether a certain railway must be constructed in a remote part of India to obtain strange supplies of material wanted for munitions. Next came a discussion and decision as to the allocation of a certain chemical, very limited in quantity, to meet the competing needs of the army, the navy, and the air service. After this, a conference on certain contracts in America valued at over £10,000,000 sterling. Next, an inspection of new inventions in artificial legs. And so on and on through a hundred-and-one topics which, as the Minister says, must confront any body of men who spend their whole days watching curves which ought always to go up and figures which ought always to swell; confronted always with the cry, "More, more, more!" and "Better, better, better!"

Returning to our own problems, let me recite a few cases of industrial unpreparedness that come prominently to mind at this time.

Before men can fight they must be fed. How few people realize that the feeding of a great people, either in peace or war, is largely a metallurgical problem with which the steel industry is primarily concerned! Not only much of our harvest yields but also the major portion of our annual sea food must be packed and preserved in tinned cans. A "tin can" is really made of sheet steel covered over with a thin wash of tin, and no other metal known can be used as a substitute. In spite of the fact that a tinned can carries only a small weight of tin, so great is our canning industry that in 1914 we imported from overseas 52,919 tons of this metal, valued at about $33,000,000. Tin is not found in paying quantities in the United States, and in 1914 only 157 tons were produced in Alaska. The principal world source is in the East Indies and the Malay States, and is controlled by Great Britain. Tin ore is also found in Bolivia and is at present being imported and smelted in New Jersey, but thus far tin from this source is only a small factor in a great industry. As has been shown, the question of our tin supply is a most important factor in our food supply. This subject, according to the daily press, is now receiving the anxious attention of our government. Had this been the case three years ago the probabilities are that any present and pressing emergency could have been forestalled.

Much of the world's supply of iron ore and coal lies right at our hand. According to the general idea, all that is necessary is to bring these things together in order to produce steel, the main prop of nations, whether in peace or war. But, among other things, steel cannot be manufactured without manganese, although this element is only a minor constituent rarely present in steel to the extent of more than one-half of one per cent. Shortly after the outbreak of the war ferromanganese was so scarce and so difficult to obtain that some steel manufacturers become panicky and the price is said to have reached the phenomenal figure of $1000 a ton for a material which in 1913 sold for about $60 and which is now quoted at $300. In the decade from 1903 to 1914 we imported from overseas over 1,300,000 tons, or about $51,000,000 worth, of this essential of our greatest industry. In the report of the Mineral Resources of the United States for 1913, published by the U. S. Geological Survey, we read that "Manganese ore mining in this country can hardly be said to have been a profitable industry. The causes are probably numerous, some of the more common being failure to explore the deposits sufficiently in advance of installation of washing equipment, lack of familiarity with the common features of the deposits in general, and possibly lack of high degree of technical skill on the part of operators."

It is all very well to accept praise where praise is due for the phenomenal growth of American industry, but none the less the government report above quoted is fairly indicative of some of the careless, slipshod methods in vogue in this country. Four years have elapsed, and a prominent New York daily paper of February 15, 1917, announces in headlines: "English Makers of Manganese Withdraw from the Market. Steel Companies Alarmed by the Serious Outlook for Ferromanganese are Feverishly Buying Manganese at Rapidly Advancing Prices."

As a matter of fact, there is ferromanganese enough in this country at present to supply our steel industry on a hand-to-mouth basis, but it is difficult to prophesy what the immediate economic effects of a stoppage of this important substance would be, especially in the event of actual warfare.

The same daily paper quoted above contains the report of the leading company of a great American chemical industry—one on which the American people would have to very largely depend for the national defence in case of war. From this report I take one brief paragraph, as pertinent to the subjects I am here discussing:

> "It is regrettable that the United States Government has made our stockholders victims of excessive taxation. Under the corporation tax and ammunition tax laws, the tax levied against our company for the year 1916 alone will result in our paying to the United States Government an amount equal to the entire profit made on sales of military powders to the United States Government by this company and its predecessors since the inception of the industry about twenty years ago. To state it another way, the tax levied against our company for 1916 under these laws will aggregate an amount equal to 170 per cent. of our entire net earnings for the year 1912, in which year we had the largest earnings in the history of the company prior to the war."

As this paper is being written the United States Government is pleading before the Supreme Court for a dissolution of the great Steel Corporation, which ought to be one of our greatest assets, whether in peace or war. Where the governments of other great nations offer coöperation and even financial assistance to the great industries on which their national safety depends, our government sees fit to oppose obstacles and discourage growth by excessive taxation. What the effect of such policies will be, should we ever be forced into a condition more serious than a mere state of war or armed neutrality, is a question which we can only hope will not have to be put to test by the final and awful eventuality.

Although awake at last, Great Britain has suffered from the same national complaint, and Dr. Alexander Findlay, in his book on "Chemistry in the Service of Man," has used words which apply quite as well to America as they do to England. They will bear repetition:

> "The crisis through which this and other European countries are now passing has brought home to us how greatly we, as a nation, have hitherto failed to recog-

nize the intimate and vital dependence of our social and national prosperity on a knowledge and appreciation of the facts and principles of science, and not least of chemistry, and on their application in industry. All the industries of the country on which not only the comfort, but even the life of the people depends—the great manufacturing industries and agriculture, the greatest industry of all—claim tribute of chemistry. And yet we, as a nation, have done much less than the responsibilities of our civilization demanded to promote and encourage the development of chemical knowledge; we have even, indeed, largely failed to avail ourselves of that tribute which science is so willing to pay. To the work of laying the foundation of pure science, on which the superstructure of successful industrial achievement must be raised, British chemists have, according to the measure of their numbers, contributed an honourable share; but the people as a whole, being ignorant of science, have mistrusted and looked askance at those who alone could enlarge the scope of their industries and increase the efficiency of their labours. And so we have witnessed in the past an appalling and needless waste of our national resources, and in too many cases industries have languished and succumbed, or, even when born under conditions of great promise, have remained dwarfed and stunted in growth. In 1862 the German chemist, Hofmann, at that time a professor of chemistry in London, could utter the prophecy: 'England will, beyond question, at no distant day, become herself the greatest colour-producing country in the world; nay, by the strangest of revolutions, she may, ere long, send her coal-derived blues to indigo-growing India, her tar-distilled crimsons to cochineal-producing Mexico, and her fossil substitutes for quercitron and safflower to China, Japan, and the other countries whence these articles are now derived.' But alas! that prophecy has not yet been fulfilled, and the industry of synthetic dyes, an industry which above all others depends on the fostering and encouragement of chemical research and on the highest scientific efficiency, has

> found a home elsewhere amid more congenial surroundings.
>
> "But there are now welcome signs that the country is awakening to a sense of past deficiencies, and already the government has taken a first short step in the direction of encouraging and assisting scientific and industrial research. But if the national effort is really to become effective and to exert a lasting influence, something more is necessary, something which is, perhaps, more difficult of achievement than governmental aid. The mental outlook and the attitude of the people as a whole towards science must be changed, and the scientific habit and a spirit of trust in science must be cultivated; and we must also attract in much larger numbers into the ranks of scientific workers men of equal mental calibre to, and capable of taking the same wide outlook as, those who are at present attracted into the higher ranks of the legal profession or into the civil services. Science stands for efficiency *in all the activities of life*, and the neglect of science spells waste and industrial decay. It is for the country to choose the path which it will follow."

A year ago I published a paper in the JOURNAL of this Institute on "The Rôle of Chemistry in the War." This paper, which was reprinted by the U. S. Senate as Senate Document No. 340, attempted, among other things, to set forth the great importance of studying methods of fixing atmospheric nitrogen for the production of fertilizers and high explosives. In that paper the effort was made to explain in simple language the absolute dependence of our people on an adequate supply of fixed nitrogen, and the danger that would ensue if war or embargo should interfere with the importation of fixed nitrogen from the nitrate beds of Chile. The air we breathe consists of nearly four-fifths of nitrogen gas, or equivalent to a weight of 33,880 tons upon every acre of land. The land needs nitrogen for the production of crops, but, except through the agency of bacteria which, curiously enough, are associated only with the root systems of beans, peas, and clovers, vegetation cannot make use of the free nitrogen of the air. Also, before it can be used for making high explosives, nitrogen must be fixed to some other element. Once thus fixed, it makes little difference to the chemist what it is joined with, as he can by one method or another manipulate it to any end product desired. Nitrogen may appear combined with other elements as a simple fertilizer for your lawn; as a deadly, treacherous explosive, an ounce of which is sufficient to wreck a building or a battleship. It may take the form of a deadly poison, cyanide, which is used to extract gold from its ores. It may be a principal constituent of a beautiful dye or a beneficent medicine. It is a constituent of the wool we wear upon our backs, of the leather on our feet. Joined with oxygen, it forms the corrosive nitric acid which dissolves nearly all metals; joined with hydrogen, it forms the familiar pungent alkali, ammonia, which neutralizes all acids. Fixed nitrogen in the form of protein makes the principal strength and value of the food we eat. Animals having absorbed it in part excrete the remainder in a different combination, and the manure goes back to the land to be used in part again. But there is always waste, and a large portion gets free and escapes back into the atmospheric ocean from which it originally came, hence the call upon the chemist to devise methods for its fixation.

During the past year there has been much discussion and agitation over the question of nitrogen fixation. Many of the great steel and smelting companies have invested large sums of money in the installation of by-product coke ovens. One of the by-products of coke making is ammonia, and it is claimed that the fixed nitrogen from this source alone would supply all the reasonable needs of the nation. Large quantities of ammonia are, however, needed for the cooling and refrigeration of the enormous meat supplies of the world, while the chemical methods used in changing ammonia to the much-needed nitric acid state of fixation present certain difficult problems which have not yet been fully worked out in this country.

By a method which is worked on a large scale at Niagara Falls, Canada, nitrogen is fixed to carbon to form a chemical compound known as cyanamide. If carbon in the form of ground coal or coke is mixed with lime and heated in an electric furnace, a carbide is formed. If air nitrogen is conducted into this substance in another furnace, the mass is converted into calcium cyanamide ($CaCN_2$), an excellent fertilizer under certain conditions. Treated with steam, this compound yields ammonia.

Nitrogen can also be fixed by passing huge electric arcs or sparks through air which is conducted between terminals enclosed in furnaces of a special type. Congress has within the past year appropriated $20,000,000 for the installation of a government nitrogen fixation process, but no announcement has yet been made as to what method the government's advisers intend to select, and it is exceedingly doubtful whether the appropriation will be large enough for the purpose, or whether, under our American conditions, such a government plant could be operated except as a losing venture.

Recently an American scientist, Prof. J. E. Bucher, of Brown University, has announced a new process by which sodium carbonate, the chemical familiar to every household under the name of washing soda, is mixed with finely-ground iron ore and coke dust and the mixture heated in a current of air to a moderate temperature. Nitrogen is fixed in the form of the poisonous sodium cyanide (NaCN). As has been pointed out, nitrogen once fixed lends itself to the chemist with great adaptation. From cyanide, ammonia and an astonishing number of useful chemicals, both of an organic and inorganic nature, can be made. The chemical changes which are proposed are too complicated for discussion in this paper, but it is interesting to note that one of the compounds which can be readily synthesized by this process is urea, a metabolic product of animal life. As urea contains 46 per cent. of fixed nitrogen and is soluble, it should be and is an intensive fertilizer. Its cost heretofore has alone excluded it from use for this purpose. Bucher's researches, which have persisted through a number of years, have been carried out with fascinating simplicity and ingenuity. It is as yet too soon to venture a prediction as to the economic and commercial success of this new method of attacking the nitrogen fixation problem, but while awaiting the verdict of the future we may be permitted to hope that this fine example of persistent American research will prove to be at least one useful way of tapping the inexhaustible treasure of the air.

The potash situation in this country since the war has been an interesting one, and, while the scarcity of this important chemical has crippled some American industries, chemists in some lines have been stimulated to work out methods of getting on without it. Before the war certain grades of glass, such, for instance, as are used for making electric-light bulbs, were potash glass. Now it is quite certain that better glass is being made in America than ever before, in spite of the potash famine. Potash, however, like fixed nitrogen, is a necessary plant food, and intensive agriculture cannot get on indefinitely without it, unless potash or the lack of it is to become a very important factor in the much-discussed high cost of living. As sold on the basis of fertilizer value before the war, potash was worth about $34 per ton. It is now quoted nominally at $400, though, owing to its practical absence from the market, sales are rare occurrences. It is perhaps needless to repeat here that practically all the normal world's supply of potash has heretofore come from mines controlled by Germany. We have unlimited quantities of potash locked up in an insoluble form in our feldspathic rocks, but it costs more than $30 per ton to get it out, so that fear of German competition after the war has prevented capital from developing the processes that American chemists have worked out for treating these potash ores. A certain quantity of potash is collected as a by-product in the manufacture of some few types of cement, and to a certain extent it is being extracted from sea-weed on the Pacific coast and from a potash-bearing mineral known as alunite, which is found in Utah. It is also, with a good deal of trouble, extracted from the brines of some of our western salt lakes, and from hardwood ashes. In all, our domestic production from all sources in 1916 was less than 9000 tons, while our yearly need at present is probably greatly in excess of 300,000 tons. The fact remains that up to date there is no potash industry in America at all commensurate with our present or future needs.

The chemistry of coal-tar has been tremendously stimulated in America within the last three years, and the manufacture of many beautiful dyes and useful chemicals and medicinals from this source, which used to come exclusively from Germany, is now firmly established in this country. The dyestuff situation has been much discussed in the daily press, and many wrong impressions have been disseminated in regard to it, in spite of the fact that a number of papers containing the simple truth have been published by chemical experts. I touch but briefly on this phase of chemistry in American industry, as the subject is one that can be discussed far better by others and is worthy of a paper by itself.

Dr. J. M. Mathews, addressing a section of the American Chemical Society, recently made some comments on the public attitude towards applied chemistry which I shall take the liberty of repeating at this place, as in a way it serves to introduce the next phase of chemical industry which I have selected to discuss in this paper. Dr. Mathews said:

> "The past two years, I think, have seen a better appreciation by the layman and the press as to just what the chemist is and what his profession consists of and can accomplish. There is still that idea, however, prevailing that chemistry is a hodge-podge of mysterious secrets, the discovery of which is made by accidental and haphazard methods. The popular mind has evidently not yet progressed beyond the age of the alchemist. In things chemical the public has still the innocently receptive mind of a child; it will accept as gospel truth the most absurd and illogical statements of supposed discoveries. Some so-called chemist announces the remarkable discovery that by the addition of a few drops of a mysterious green liquid to water he creates a perfect substitute for gasoline for use in automobiles. The daily press devotes column after column to this truly remarkable process, and the public evidences the keenest and most serious interest. The thing could not be more absurd than if a physician announced that he had discovered that he could make new legs grow where those members had been amputated, by rubbing a decoction of hen's teeth on the parts affected. I hardly believe either the press or the public would take this latter announcement seriously, and any editor would consider it too foolish to be printed. And yet how often have we been regaled at the breakfast table with glaring headlines announcing with all seriousness that Dr. So-and-So, a celebrated chemist (whom none of us had ever heard of before), had just discovered the *secret* of the German dyes."

The war, as well as the enormous domestic growth in automobile traffic, with the inevitable rise in the price of motor fuel, has naturally stimulated the study by American chemists and engineers of the whole motor fuel question. There are a number of different lines along which this problem can be attacked. Benzine, or benzol, one of the many by-products of coal-tar distillation already referred to, may some day be cheap enough in this country to use as a motor fuel, either alone or mixed with gasoline. Again, engines can be designed to burn denatured or industrial alcohol, and chemistry has already devised practical methods for making so-called grain or ethyl alcohol out of sawdust and other woody waste material. This presents an interesting possibility from the conservation standpoint, because when we use up petroleum or coal we have consumed just that much of a natural resource that will never come back to us again. But alcohol can be made from crops that are planted and thus renewed from year to year. Since alcohol can also be made from any starchy plant, it would not be impossible to contemplate at some future time growing our motor fuel each year, just as we now grow potatoes and corn. Moreover, in the making of alcohol, bacteria and other microscopic organisms are put to work in the service of man, a fascinating source of energy that will probably be exploited by our posterity to a much greater degree than it has up to the present time.

Whatever may be the final solution of the motor fuel question, it seems quite certain that for some time to come the natural petroleum deposits of the earth will continue to furnish the bulk of our liquid fuels. In addition to the large petroleum resources of North America, South American sources have not yet been fully explored, while the extraordinary petroleum wells in the Mexican field promise a practically inexhaustible supply of raw material.

The Mexican oil fields, however, though developed and owned by American capital, are left open and unpoliced by our government, ready to be grabbed by any foreign government or even any group of bandits strong enough to take possession. Such possession would constitute a very considerable balance of power in world affairs to-day, and the recapture would call for an untold expenditure of blood and treasure, perhaps to no purpose, as a retreating enemy can destroy oil wells, tanks, and pipe lines so that years must pass before they can again become available. This danger has been emphasized by the terrible destruction in the oil fields of Roumania and Galicia.

It is a fact not generally known that a great many of the large petroleum deposits of the world contain little or no light-boiling constituents which we call gasoline or naphtha and which are known in Europe as petrol. The petroleums of the mid-continental field of the United States yield from eight to twelve or even fifteen per cent. of natural gasoline, but some of the California, Texas, and all of the Mexican petroleums contain very little of the lighter boiling fractions suitable for motor fuels. Now, to use an analogy, if we have large, heavy pieces of stone or other solid materials which we wish to make more conformable for certain purposes, we usually crack up the large pieces into smaller ones and then screen the pieces into lots of more or less approximately even size, and sometimes we wash the resulting materials to remove adherent dust and impurities. Now, this is precisely analogous to what chemistry is doing to heavy hydrocarbon molecules, of which natural petroleum, as it exudes from below the earth's surface, is constituted. By a process known as fractional distillation under pressure the heavy molecules vaporized and put into rapid movement by the heat might almost be said to crack themselves into pieces by violently colliding with each other and with the walls of the containing vessel. This is the process actually known as "cracking," by which the percentage of gasoline is artificially increased so that we obtain a greater yield than Nature had originally provided in the crude oil. But just as in our analogy the screens separated the cracked stone into various sizes, the distillation separates the oil into fractions, the dust of which appears as a permanent gas which cannot be liquefied and shipped, but must be locally burned as fuel or piped away. The next lot of fine screenings, say of sand-grain dimensions, might represent the ethereal liquids known as naphthas, petroleum ethers, or rigolines. Next come the analogues of the fine-grained gravel sizes used for gasoline motor fuels, next the coarser gravel size representing the kerosenes, then the still larger sortings corresponding to the lubricating oils, and finally the larger lumps—the axle greases, asphaltic pitches, and solid paraffins.

The fuel oils on which the navies of the world are rapidly coming to depend may be considered as a mixture of all these fractions after the lightest or finest have been removed and the heaviest and coarsest left behind.

Now, no analogy is perfect, and the one used above must not be pushed too far, but it serves a very good purpose in making clear to the general reader the answer to a number of questions which are constantly being asked.

If the supply of crude oil is so abundant and if the cracking process is efficient, why should not the supply of gasoline keep pace with the increased demand, however great that may become? Just as it is impossible to crack a stone boulder into pieces all of one desired size, it is impossible to carry on the cracking of petroleum except within certain prescribed limits. Moreover, a process which would crack up one kind of stone efficiently would fail entirely with another. Thus an oil-cracking process which might increase the yield of gasoline from eight to twenty-five per cent. on a mid-continental oil might not work at all on a Mexican or some other type of oil.

Why is it that some of the gasolines offered for sale to-day are degraded and will not start our engines in cold weather as well as used to be the case in earlier days? Simply for the reason that, as the demand grows more rapidly than the supply, the tendency is, following our analogy, to slightly increase the size of the holes in one of the screens so as to let more of the kerosene sizes mix in with the gasoline. If we want all fine screenings, we must so specify and pay the price, but gasoline is not manufactured to specification, and, so far as the public is concerned, it has nothing to say about the size of the holes in the screens.

In reality, of course, the distillation of oils has nothing to do with screens, but depends upon the temperatures at which the cuts on the different fractions are made. It is now clear, from what has been said, that when the chemist is through with the problem he turns it over to the engineer. If the engineer can design an engine that will start and operate as efficiently with a degraded gasoline, so much the better for all concerned. The producer will be helped out of many a trouble, and the consumer will get a cheaper fuel. But the chemist is not yet through with his end of the problem; he is beginning to find out that if he cannot simply crack up certain kinds of oils to make satisfactory motor fuel, he can first crack them up to the finest fragments and then put the fragments together again into new aggregated pieces or molecules which serve his purpose.

Since we have been dealing in analogies, let us suppose that a dairyman had been separating ten or twelve per cent. of cream from his milk and making it into butter, getting whatever he could for the skimmed milk that was left. Then suppose that a chemist came forward and proposed to treat the skimmed milk in some manner so that another ten per cent. of cream could be separated, and the second crop of skimmed milk treated again to make a third lot of cream, after which two treatments the skimmed milk still remaining was at least as good for every purpose it could possibly be used for as it was at first. It is just this sort of thing the chemist is now at work on for the motor-fuel industry, viz.: to take the oil distillates, after all the gasoline has been removed, and treat them so that another crop of gasoline can be taken off, this treatment to be repeated as often as it pays to do so, the residue being still available as a fuel oil. At best such reprocessing could not go on indefinitely, for at each treatment of the oil distillates some free carbon or coke is split off from the molecules, and is a waste, so that such a method is by no means capable of getting something for nothing, although it has very practical possibilities. The daily press has from time to time got hold of a few details of the investgiations of some of the workers in this field, and has reverberated with exaggerations of the wonders that have been accomplished.

It is one thing, however, to work on a problem of this kind on the laboratory scale of operation, and quite another to adapt a new process to the big commercial scale of operation, as those of us who have had experience along these lines can most keenly realize. In working out such difficulties, the chemist and the engineer must join hands or, better, must exist in one and the same person, a member of that most modern of all professions, chemical engineering. Very often metallurgy must be called upon to develop new alloy steels especially made to exhibit great strength at comparatively high temperatures, while quite new types of machinery must be designed and tried out in service. Sometimes mistakes will be made and discouraging setbacks will occur, but, however great the obstacles and discouragements, the work goes on, for it is mainly by his mistakes that man learns to accomplish results in a few minutes or hours that Nature has taken her time over for untold ages. How long it takes Mother Earth to make a ruby or an emerald we do not know any more than we know how long it took her to make gasoline. Given the raw materials, we can make all these and many other things in a few hours, but chemists working in these fields have labored patiently and lain awake very many discouraged nights before success was achieved, and then nine times out of ten, yes ninety-nine times out of a hundred, the credit is given to some well-advertised worker who merely began from some vantage-ground that somebody else had painfully climbed to.

Although not the result strictly of American chemical research, I would like to include in this paper some account of the wonderful work of chemistry in making synthetically from well-known raw materials useful substances that have heretofore been extracted from the sap of trees and plants indigenous to tropical or semi-tropical parts of the world. Among such substances we may particularly mention indigo, camphor, and rubber. Man-made indigo is already an article of commerce, while the manufacture of the other two has already been accomplished. Dr. Duisberg, a German scientist, was already able to say in 1912:

> "The end in view is this: that artificial rubber may soon play as important a rôle in the markets of the world as does natural rubber. The consumption of rubber is simply enormous. Finished articles to the value of three milliard marks are manufactured every year, and the raw material from which they are made, calculated at the present market price of 12 marks per kilo, costs one milliard marks. Other tasks which the chemist has on hand shrink into insignificance compared with this gigantic problem. The laurel wreath will not adorn the brow of the wild dreamer, but that of the scientist who, cool and persevering, pursues his way. The seed he sows ripens slowly, and though, according to the statements in the press, all this is mere child's play and the problem has been solved, I leave it to your judgment whether this is true or not, like much that printer's ink patiently transfers to paper. I am right in the midst of this excitement. I have employed articles made of synthetic rubber, and for some time I have used automobile tires made of this material. Yet, if you ask me to answer you honestly and truly when synthetic rubber will bring the millions which prophets see in its exploitation, I must reply that I do not know. Surely not

> in the immediate future, although synthetic rubber will certainly appear on the market in a very short time. But I hope to live long enough to see Art triumph also here over Nature."

The subject of chemistry and American industry covers too wide a field to be treated more than sketchily in a single paper. I have not space to refer to many interesting chemical developments in the field of metallurgy, of textile manufacture, of foodstuffs and medicinals, and last, but not least, of photography and the moving-picture film, destined to have so profound an influence on the education of the people. If what I have here written will stimulate the slightest interest in an appreciation of the usefulness and place of chemistry in our national development, my time will have been well spent.

I have endeavored to point out a few of a great many needs on the chemical side of industrial development in America. I have also ventured to point out what seems to me to be a national shortcoming, in the lack of interest and prevision exhibited both by our people and our government in regard to certain important factors of industry. Whatever has been stated is said in no spirit of carping criticism, but with the purely patriotic hope that a new leaf may be turned in the study of reasonable preparedness, whether in peace or war.

If we can have a Federal Reserve for money, why not a Federal Reserve for the necessities of our people that we do not adequately produce within our own boundaries?

A former president of the American Chemical Society, Mr. A. D. Little, once used words to this effect:

> "We have in this country the capital, the enterprise and the chemistry for great industrial achievements. That we cannot thus far point to them is due to the fact that with us chemistry is too often left like Cinderalla sitting beside the ashes of the laboratory furnace, while her two haughty sisters drive away to the industrial ball."

The Fairy Godmother in this case must be an awakened and intelligent public opinion which will be reflected in government, to the end that chemistry, capital, and enterprise shall be treated with equal appreciation and a fair and just generosity.

MULTIPLEXING IN CABLE TELEGRAPHY.*

BY

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THE use of alternating currents in cable telegraphy offers the great advantage that multiplexing is made possible. Among the many schemes which may be utilized, the method of using separate cables for sending and receiving, transmitting several messages on one cable and receiving a corresponding number on another, seems to offer the best solution of the problem where the volume of traffic warrants. In such an arrangement, we eliminate at once the artificial cable, which is an indispensable element in duplexing, and at the same time get rid of all the troubles incidental to the accurate balancing of the duplex bridge.

It must be remembered that the transmitted current is very large as compared with the received current, and any deviation from perfect balance in the ordinary method of duplexing may introduce disturbing effects on the receiver which would completely mask the effect of the received current. Even in using very low frequencies, say 5 cycles per second (150 cable letters per minute), the ratio of the transmitted to the received current in a long cable is about 20,000, and this ratio increases very rapidly as the frequency is increased. It is obvious that to balance out the large transmitting current to a sufficient degree so as not to affect the receiver is a difficult matter, and limits the speed of signalling, because the sensitiveness of the receiver is limited. But, even with all the refinements in balancing, the most that can be accomplished at present is the simultaneous sending and receiving of one message at each end of the cable.

In the plan proposed here of using two separate cables, one for sending and the other for receiving, the difficulties from balancing are completely done away with, and at the same time the working capacities of the cables can be greatly increased, a number of messages trasmitted on one cable, and a corresponding number received on another cable.

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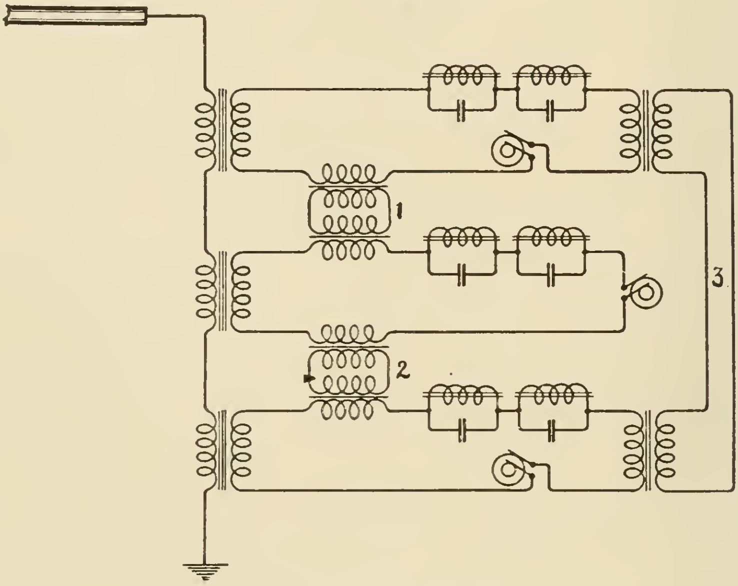
* Communicated by the Author.

The method proposed is shown schematically in the two accompanying figures. In Fig. 1 an arrangement is shown for transmitting three messages simultaneously on one cable. We have here three local transmitting circuits coupled to the cable, the frequency of each transmitter being different from any one of the others, say 6, 8, and 10 cycles. In each local transmitting circuit two loop circuits are included which are separately tuned to the frequencies of the other two transmitters, offering thereby a high impedance to the current flow of these frequencies, thus preventing the transfer of current from one transmitting circuit to the others. To further check any transfer of current fom one local circuit to another, the intermediate circuits 1, 2, and 3 are introduced through which e. m. f.'s of opposite phase to that induced by way of cable transformers are induced, and thus balancing out and residual effect from one circuit on another.

FIG. 1.



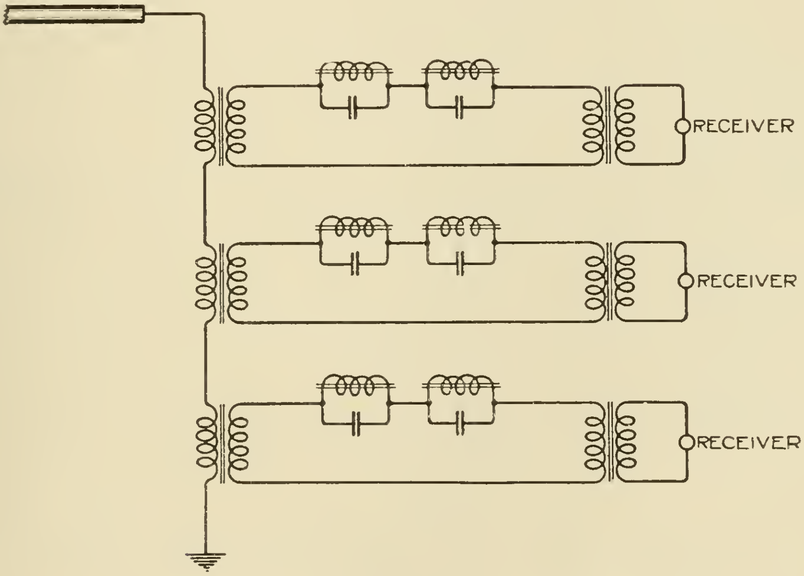
Transmitting terminal.

In Fig. 2 a receiving terminal of a cable is shown in which three circuits are used for the reception of three messages simultaneously. Each receiving circuit is coupled to the cable through an intermediate circuit. In each intermediate circuit two loop circuits are included which are separately tuned to the frequencies of the signals which are to be excluded from that particular receiver, each receiver responding accordingly only to a signal of one predetermined frequency and excluding the others. If desired, loop circuits may also be introduced in the receiver circuits, and thus further increase the selectivity.

In the arrangement described above, the disturbing effects of local transmitter on receiver, which are always present to a greater or less degree in duplexing, are entirely eliminated, and as a consequence detectors and amplifiers of very much greater sensitiveness may be employed.

For purposes of illustration three transmitters and three receivers are shown, so that two cables could handle three messages both ways, but obviously the method outlined above is not limited to this number. It would be necessary, of course, to increase somewhat the complexity of the circuit arrangements, increasing the number of loop circuits and intermediate circuits employed in the transmitting and receiving circuits, but this would not offer any serious difficulties. The experience with radio telegraphy offers a similar case, although, of course, the ratio of the transmitting current in the sending antennæ to the receiving current in the receiving antennæ is very much greater than 20,000, as is the case in an ocean cable. The practical solution at present used in radio telegraphy is to employ two separate antennæ, one for transmitting and one for receiving, the pair furnishing the complete

FIG. 2.



Receiving terminal.

telegraph terminal. The plan outlined above for the case of ocean cables is similar in principle and is proposed for similar reasons.

The present war has emphasized the supreme importance of ocean cables as never before in the history of the world, and as a result it is believed that as soon as peace is established it will be well worth while to carefully consider a comprehensive plan of cable laying based on the maximum of international service.

WASHINGTON, D. C., April 17, 1917.

A Plate Fulcrum Track Scale. J. H. A. BOUSFIELD. (*Railway Age Gazette,* vol. 62, No. 10, p. 395, March 9, 1917.)—The Pennsylvania Railroad, one of the pioneers in the use of plate fulcrum track scales, recently installed the first two-section track scale of this type at Pitcairn, Pa. This form of construction eliminates the knife-edges which have been of practically universal application in scales of all kinds. In consequence of this change, the need for regrinding and renewing knife-edges and bearings is avoided. Similarly, dead rails or their equivalent in the form of relieving gears are avoided. As indicated by the name, a thin plate, continuous from lever to bearing, takes the place of the knife-edge. These plate fulcrums consist of relatively thin central portions connecting two heavier portions or heads. The thin portion gives the desired flexibility, while the large heads distribute the load on the supporting members and decrease the unit stresses. The thin central portions are all arranged to act in direct compression, but are subjected to a slight flexure as the weighing beams vibrate and the lever system responds to the condition of balance. Thus the necessary vibration is taken care of without entailing the inevitable wear that takes place with the knife-edge scale, and the thin plates of steel remain in their original condition, regardless of the amount of weighing that is done by the scale.

The effective length of the weighing rail is 52 feet. The scale is of the two-section type, wherein four main transverse levers—two at each end of the track-supporting girder—transmit the load to two longitudinal extension levers, which in turn transmit to a transverse extension lever connected directly to the weighing beam. Only seven levers are used in the scale, thus effecting greater simplicity in construction than in the four-section type of scale with equal efficiency. The main girders are so designed that a test car can be placed directly over the centre line of a section, thus providing an effective means for accurate calibration. The main weighing beam is graduated to 300,000 pounds by 1000-pound notches and a fractional bar to 1000 pounds by 50-pound notches. An auxiliary weight is provided to raise the capacity to 400,000 pounds. The plate fulcrum principle is that used for many years in the highly refined Emery testing machines.

FERROMANGANESE IN THE IRON AND STEEL INDUSTRY.*

BY

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1. INTRODUCTION.

At the present time, and for the past two years, the situation in this country relative to a dependable supply of manganese ores, and also ferromanganese alloys for use in iron and steel metallurgy, has been extremely serious. The situation will remain so as long as the European war continues, and will no doubt become acute in the event of this country becoming involved in the conflict. Before the war ferromanganese was not produced in this country except by one company in any amount, and practically no manganese ores were mined. Manganese mining has never assumed the proportions of an industry in the United States because of the small extent and scattered nature of most of the deposits. Further, most steel makers felt no urgent necessity for producing ferromanganese, nor were independent makers disposed to enter the field, for the reason that an abundant supply of the alloys had always been obtainable from foreign sources, and usually at exceedingly reasonable prices, say $45 per ton, seaboard.

The manganese ore used in this country in the manufacture of ferromanganese has been hitherto mainly secured from three principal sources; viz., Russia (southern), India (southern British), and Brazil (east central). For a large number of years these three countries have outranked all other producing countries in the output of manganese ores. For the five years preceding the European war, Russia produced annually about 844,000 long tons, India 694,000 long tons, and Brazil 200,000 long tons.[1] Both the Russian and Indian outputs have suffered a falling off since the war started, but the Brazilian output has increased by leaps and bounds until its 1916 production is rated at about 650,000 tons, as near as can be estimated from figures available. Prior to the war a large amount of our imported manganese ore came from India and *via* Germany and England. At the present writing Brazil is the principal foreign source.

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* Communicated by the Author.

[1] Singewald, Joseph T. Jr., and Miller, Benj. L., "The Manganese Ores of the Lafayette District, Minas Geraes, Brazil," in *Bull. A.I.M.E.*, October, 1916, p. 1745 *et seq.*

Since the war started, the receipt of both ores and alloys from the belligerent nations and their colonies has been decidedly uncertain, and this, together with the embargoes laid by England at different times, made necessary the taking of the Brazilian output in large amount. The manganese ores of India have been shipped mainly to England, while the shipment of those from the Russian Caucasus practically ceased when Turkey entered the war with the concomitant closing of that valuable exit, the Dardanelles. Hence it is clear that, of the three important producing countries, but one has been able to furnish ores continuously, and this has been done by Brazil. As will be further mentioned later on, it would seem as though the time were opportune for reopening the abandoned Chilean deposits, which are now much more available through the opening of the Panama Canal and also through the exploitation of iron ores there at present. The shipment of Chilean manganese ores should go a long way toward making up the deficit caused by the curtailment of shipments from India and the complete blocking off of the Russian ores.

The ferromanganese alloys have not been received in any quantity since the war started, and of necessity a new domestic industry has arisen in this country; viz., the production of ferromanganese for the market. Prior to the war, England furnished most of the ferromanganese used here (*i.e.,* the high percentage (80 per cent.) alloy), and Germany shipped a subordinate tonnage. As already pointed out, English embargoes at different times since the war started cut off imports, and no shipments have been received from Germany. Germany, of course, has no ferromanganese to sell even if it were possible to get it out of the country, being practically at starvation ebb for steel-making supplies, and particularly manganese, if reports are true. The decrease in imports, together with the terrific pace of steel production in the past two years, quite naturally caused a heavy demand for ferromanganese, and, consequently, heavy increase in prices. Prices were high indeed, and manipulations of the market by speculative traders carried the quotations to unheard-of levels.

2. SOURCES OF MANGANESE ORES.

The main sources of manganese ores, as already mentioned, are the producing mines of Russia, India, and Brazil. The geological occurrences of the ores have been described at some length in the scientific press by Harder,[2] Drake,[3] and others, and any further account in this article appears to be superfluous. Very briefly, the ores of Russia have come in the main from the Tchiatouri deposits in the central part of the Caucasus, and some ore has been produced in the Nikopol district. The mode of mining was, until about ten years ago, exceedingly primitive, being conducted by peasants, but of late years foreign capital has become interested, and modern methods of extraction have been installed.

The manganese ores of India have been described mainly by Fermor,[4] and also Harder.[5] The ores occur at a large number of localities, but the only deposits of known economic importance are those of the Jhabua district of Central India; the Panch Maháls district of Bombay; the Chhindwára, Bálághát, Bhandára, and Nágpur districts of the Central Provinces; the Sandur and Vizagapatam districts of Madras; the Shimoga district in Mysore; and the Gangpur district in Bengal.[6] There are a number of operating mines producing high-grade ores in which the manganese shows 50 per cent. and more on analysis. Ore blocked out and in reserve indicates that these mines will be in a position to be constant producers for many years to come.

Manganese ore is known in Brazil in the states of Bahia, Minas Geraes, and Matto Grosso. The mining of the ores dates back to 1894, the main bulk of the output having come from Minas Geraes. The districts have been described by Singewald and Miller,[7] Harder,[8] Scott,[9] Derby,[10] *et al.* In late years the

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[2] Harder, E. C., "Manganese Ores of Russia, India, Brazil, and Chile," *Bull. A.I.M.E.*, May, 1916, p. 761 *et seq.*

[3] Drake, Frank, "The Manganese Ore Industry of the Caucasus," *Trans. A.I.M.E.*, xxviii, pp. 191–208, 1898.

[4] Fermor, L. L., "The Manganese Ore Deposits of India," "Memoirs Geological Survey of India," vol. xxxvii, pts. 1–4.

[5] Harder, E. C., *loc. cit.*

[6] Harder, E. C., *loc. cit.*

[7] Singewald, Joseph T. Jr., and Miller, Benj. L., *loc. cit.*

[8] Harder, E. C., *loc. cit.*

[9] Scott, H. K., "The Manganese Ores of Brazil," *Jour. Iron and Steel Inst.*, No. 1, 1900, p. 189.

[10] Derby, O. A., "On the Original Type of Manganese Ore Deposits of the Queluz District, Brazil," *Am. Jour. Sci.*, 4th ser., vol. xxv, pp.213–216, 1908, and "On the Manganese Ore Deposits of the Queluz (Lafayette) District, Minas Geraes, Brazil," *Ibid.*, 4th ser., vol. xii, 1901, pp. 19–23.

Queluz or Lafayette district of Minas Geraes has outstripped the Miguel Burnier district nearby with the development of the phenomenal Morro da Mina mine, so that the Lafayette district has assumed foremost importance in Brazil. Development work has disclosed an ore reserve of about 10,000,000 tons, and the mine is producing at the rate of over 200,000 tons per annum.

As previously alluded to, manganese ores have been mined in Chile; the industry was carried on quite extensively prior to 1900, or about the time when the extensive Indian deposits began to be exploited. Since 1905, practically no manganese ore has been mined in Chile, and the mines have been abandoned. Manganese ores occur in the Huasco and Carrizal districts of Atacama; the Los Chorros, Los Cañas, La Liga, Arrayan, and Corral Quemada districts of Coquimbo, and the Aculeo district of Santiago. Most of the exported Chilean ore came from the Carrizal and Corral Quemada districts, and a considerable tonnage from Los Cañas and La Liga.

Manganese mining has never been an important industry in the United States on account of the scattered and discontinuous nature of the deposits.[11] Deposits are found in many localities, but in only a few places do they occur in sufficient quantity to be of high commercial value. Ores have been mined in the New England, Appalachian, and Piedmont regions in the eastern United States, in northern Arkansas, and to a small extent in California in the central western part. The main mines as to production have been those in the Blue Ridge and the James River-Staunton River region of Virginia, the Cartersville and Cave Spring districts of Georgia, the Batesville district of Arkansas, and the Livermore Telsa district of California.

3. PRODUCTION OF FERRO-ALLOYS; AND THE TRADE SITUATION.

In 1914 there was only one company that made ferromanganese this side of the Atlantic, and none of this production was sold in the open market; it was all used for private needs. Most of the spiegeleisen prior to 1914 was made in Pennsylvania from a manganiferous residuum that is a by-product from a zinc smelter. About 90,000 tons of the total of 106,980 tons made in 1913 were made at that point; the remainder was turned out by a Colorado plant and by an Illinois steel plant for their exclusive use in the manufacture of Bessemer steel. In 1913 the United States was the only country which did not make its own total consumption of ferromanganese, which, in the light of the importance of its steel industry and the fact that the other countries making their own ferromanganese draw their ore from outside sources, appears to be a rather singular thing.

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[11] Harder, E. C., "Manganese Deposits of the United States," *Bull. 427, U. S. Geological Survey*, 1910.

The history of the manufacture of ferromanganese in the United States dates from the outbreak of the European war, summer of 1914. It appears that in no other substance entering intimately into the manufacture of steel have the war and the conditions brought about thereby produced such a radical effect upon domestic production and demand as in ferromanganese. The war itself, and coincident industrial activities, showed clearly the dependence of American steel makers upon European sources to furnish an adequate supply of one of the most essential ingredients in steel-making processes. Nor was there any vital reason for this, other than the excuse that foreign ferromanganese was cheap and abundant and prior to 1914 there was no indication that the supply would ever be cut off. As in the dye industry, this indicates the alarming improvidence of American manufacturers. England and, in a lesser degree, Germany, who have furnished the greater part of the ferromanganese used in this country, have made the alloy from imported ores, coming from Russia, India, and Brazil. It appears, in the light of the developments of the past two years, that the manufacture of ferromanganese on a commercial scale has come to be an important domestic industry, but it will remain so only so long as we have an abundant supply of ores. The closer trade relations which have been secured with South American countries seem to indicate that the greater portion of our manganese ore will come from Brazil in the future.

No one probably has ever doubted the ability of American metallurgists to produce both ferromanganese and spiegeleisen of as good a quality as the foreign products. Prior to 1915, practically the only producer of ferromanganese in this country was the United States Steel Corporation. This corporation required such large tonnages of both ferromanganese and the lower quality alloy that it could not run the risk of depending on imported products and market speculations, so that it met its own requirements, and almost entirely from imported ore.

During 1915 three independent steel companies commenced making ferromanganese; these concerns were the Colorado Fuel and Iron Company, the Jones & Laughlin Steel Company, and the Maryland Steel Company. Several other concerns also made ferromanganese and spiegeleisen for the market, as follows: The American Manganese Manufacturing Company, which controls the Dunbar, Pa., blast furnace; the Noble Steel Company, of San Francisco, and the Electro-Metallurgical Company, of Niagara Falls: the last two operate electro-metallurgical processes for production. The American Manganese Manufacturing Company has made elaborate plans for the production of merchant ferromanganese at Dunbar, and both the high alloy and spiegeleisen have been made. The story of the production of both ferromanganese and spiegeleisen in this country in 1916 is unequalled in the annals of the steel trade. Had not the demand for both had been met at home, the record year in steel production would never have been chronicled. The past year was no doubt the most remarkable both as to production and consumption. The imports of ferromanganese from England, which had been 28 per cent. of the total consumption in 1915 and from 45 to 60 per cent. for several years before the war, fell off to 25 per cent. in 1916. The production of spiegeleisen was the largest since 1907, when the Bessemer process was at its height (see Table I), amounting to 170,000 tons, as compared with 114,556 tons in 1915.

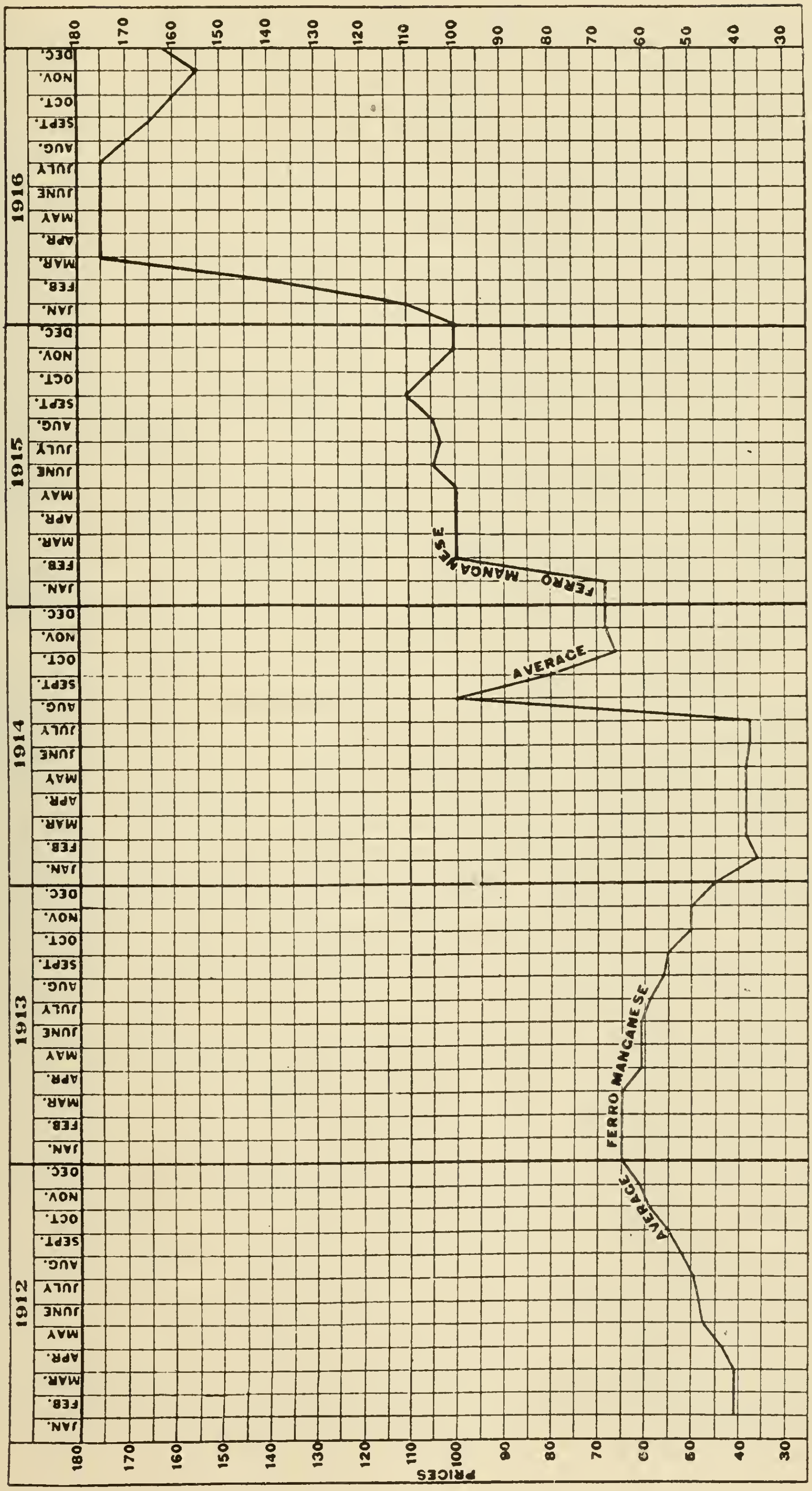
TABLE I.*

Imports and Domestic Production of Manganese Alloys: Imports of Ore.

	Production		Imports		Imports
	Ferro-manganese	Spiegeleisen	Ferro-manganese	Spiegeleisen	Manganese ore
1916	270,000†	170,000†	95,000†	......	575,000†
1915	144,260	114,556	55,263	200	313,985
1914	100,731	76,625	82,997	2,870	283,294
1913	119,495	106,980	128,070	77	345,090
1912	125,378	102,561	99,137	1,015	300,661
1911	74,602	104,013	80,263	20,970	176,852
1910	71,376	153,055	114,228	25,383	242,348
1909	82,209	142,831	88,934	16,921	212,765
1908	40,642	111,376	44,624	4,579	178,203
1907	55,918	283,430	87,400	48,994	209,021
1906	55,520	244,980	84,359	103,268	221,260
1905	62,186	227,797	52,841	55,457	257,033

* *The Iron Trade Review*, January 4, 1917, p. 24. †Estimated.

Fig. 1.



Contract prices for ferromanganese, tidewater, 1912–1916. (From the *Iron Trade Review*, January 4, 1917, p. 25.)

About a dozen furnaces produced ferromanganese or spiegeleisen during the past year, either for sale in the open market or for private consumption. Furnaces operated on manganese alloys at Dunbar, Cornwall, Sheridan, Newport, and Lebanon, Pa.; Chicago, Ill.; and also steel work blast furnaces at South Chicago, Ensley, Pittsburgh, Sparrows Point, Pueblo, and elsewhere. The Kittanning stack, Pennsylvania, produced some ferromanganese for the Jones & Laughlin Steel Company, and some production was made by the electric furnace process at Heroult, Cal. The domestic makers in 1916 not only produced 75 per cent. of the home consumption, but both ferromanganese and spiegeleisen were exported to Canada, Italy, Sweden, Holland, Australia, etc. A small amount of Indian ferromanganese was also imported. Prices in 1916 reached figures hitherto unparalleled. Spot ferromanganese sold at above $450, seaboard, the highest figure reached since the Russo-Japanese War. Spot spiegeleisen touched $100, furnace, during the same time. The prices of ferromanganese, as compiled by *The Iron Trade Review*, are given in Fig. 1.

4. THE USE OF MANGANESE IN THE METALLURGY OF IRON AND STEEL.

In every process of steel metallurgy it is common to employ one, and often more, of the ferro-alloys, according to the kind of steel being made and the use for which it is destined. By reason of total tonnage consumed, ferromanganese is the most important of the ferro-alloys. Its importance may be realized when it is said that its use is virtually indispensable. In a recent paper,[12] F. H. Willcox, of the U. S. Bureau of Mines, pointed out the great importance of manganese in the metallurgy of steel. The scientific press has not generally recognized the significance of manganese; the trade journals have called attention to our dependence upon foreign sources and have urged the matter of research to develop substitutes for both ferromanganese and spiegeleisen. In view of the well-known action of both alloys in the metallurgy of steel, it is needless to recall their effects here. However, it may not be out of place to sketch the possibilities of substitute deoxidizers and the means of securing data thereon. In any event, the scientific method of attack is the practical one.

Ferromanganese and spiegeleisen, aside from their recarburization effects, are added to steel for the purpose of deoxidizing the metal and for the purpose of removing gases and oxides therefrom. In general, the following substances mainly have been used as deoxidizers and purifiers: ferromanganese and spiegeleisen; aluminum, ferrosilicon, and ferrotitanium, either carbon-free or not. To a much less extent, the following substances have found application for the same purpose: ferro-aluminum; ferromanganese-silicon, or, as it is more commonly called, silico-manganese; ferro-silico-manganese-aluminum; ferro-silico-aluminum; silico-calcium-aluminum; ferro-vanadium; calcium-silicide; ferro-calcium-silicide; ferro-titanium-aluminum-silicide, and some others.

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[12] Willcox, F. H., "The Significance of Manganese in American Steel Metallurgy," Bull. A. I. M. E., February, 1917, p. 99 *et seq.*

Ferromanganese.—As already pointed out, manganese, in the form of one of its iron alloys, is the most important deoxidizer known. As commonly recognized, ferromanganese is an alloy of about 80 per cent. Mn, 15 per cent. Fe, and 5 per cent. C. Strictly speaking, it is rather more of a manganese alloy than one of iron, although it is classed with the ferro-alloys. Spiegeleisen is a low-grade iron-manganese alloy of about 10 to 25 per cent. Mn, and occasionally up to 35 per cent. Mn, and about 5 per cent. C. The higher-percentage alloy hastens the chemical reactions in the steel more rapidly than does the lower-percentage alloy, and accordingly absorbs less heat in so doing. Certain advantages are found in using the higher alloy; among other things, a smaller quantity of the former will be required to produce the same results, and consequently the loss through volatilization and for other reasons, when added in the solid state, will be minimized. This point will be dealt with at greater length in a later paragraph, as it is an important one.

Ferromanganese is used in cases where it is undesirable to materially increase the carbon content of the metal, as happens when spiegeleisen is added. The former is therefore of great importance in the manufacture of manganese steels. Typical 80 per cent. English ferromanganese may analyze as follows: 80.00 per cent. Mn, 7.20 per cent. C, 0.80 per cent. Si, 0.18 per cent. P, 0.004 per cent. S, and 11.20 per cent. Fe.[13] Spiegeleisen has found and still does find extensive application in the manufacture of Bessemer steel, although at present ferromanganese is used in conjunction with it in this practice. A typical English spiegeleisen analyzes 20.11 per cent. Mn, 4.99 per cent. C, 0.42 per cent.

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[13] Carnegie, D., "Liquid Steel."

Si, 0.074 per cent. P, and S nil.[14] Irrespective of which alloy is added, and whether in the steel-making appliance or in the ladle or both, certain chemical reactions occur. The manganese, by reason of its greater chemical affinity for oxygen, robs the iron or steel bath of the dissolved iron oxides with the formation of manganese oxide (MnO), which is insoluble in the metal. The MnO joins the slag, and the reduced iron is given up to the bath according to

$$Mn + FeO = MnO + Fe.$$

The deoxidizing effect of manganese is very potent, but it will not remove the last traces of oxides from the metal, nor will it remove dissolved gases; *e.g.*, nitrogen. The last traces of oxides may be scavenged out by the use of aluminum or titanium alloys, after the addition of the manganese. In addition to its action upon oxides, manganese is valuable because of its chemical reaction with sulphur. In a frozen steel, sulphur, unless sufficient manganese be present, is in the form of ferrous sulphide (FeS), which is thrown out to the crystal boundaries in such a manner as to give rise to extreme weakness and brittleness of the metal when hot. Manganese has a greater chemical affinity for sulphur than has iron, so that, when added to steel, manganese sulphide (MnS) is formed in whole or in part, dependent upon the percentage of manganese added, according to

$$Mn + FeS = MnS + Fe.$$

Some of the MnS may go to the slag, and some of it remains in the metal as rounded inclusions.

Aluminum.—This metal will remove traces of oxygen from steel when added in small amounts. Aluminum is a more efficient deoxidizer than either manganese or silicon, but its use is not entirely without certain disadvantages. The element, when added to molten steel, reduces ferrous oxide according to

$$2\ Al + 3\ FeO = 3\ Fe + Al_2O_3.$$

As the equation shows, the reaction produces the very highly infusible Al_2O_3. As the temperature of the bath is usually below the melting-point of this oxide, the tendency then is for the aluminum oxide to remain occluded in the frozen metal instead of entering the slag as desired. The use of too much aluminum tends toward the production of large pipe, and for this reason some railroad engineers specify that it must not be used as a deoxidizer for rail steel. Further, it has no effect upon sulphur. The benefits gained from the use of aluminum arise from the exothermic reaction induced on combining with oxygen, and since, on its addition, the metal is killed and thereby quieted, segregation is decreased. However, it cannot be used as a substitute for manganese because of its limitations.

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[14] Carnegie, D., *loc. cit.*

Ferrosilicon.—This alloy, formerly made in the blast furnace as a highly silicated pig iron containing from 10 to 12 per cent. Si, is now made in the electric furnace and may contain up to 95 per cent. Si. Typical English ferrosilicon made in the blast furnace analyzes 13.45 per cent. Si, 1.21 per cent. C, 1.71 per cent. Mn, 0.058 per cent. P, and 0.02 per cent. S. Ferrosilicon made in the electric furnace may contain 25 to 35, 45 to 50, 75 to 80, or 90 to 95 per cent. Si. A typical English electric-furnace ferrosilicon analyzes 94.8 per cent. Si, 0.08 per cent. Mn, 0.01 per cent. P, 0.02 per cent. S, and C *nil.* The 25 to 30 per cent. ferrosilicon may be used to advantage in large pieces in both the open-hearth and Bessemer processes. Ferrosilicon is, as a rule, added to steel in the furnace, but occasionally in the ladle before the steel is tapped. Ferrosilicon is very effective in steel metallurgy because of the high chemical affinity of silicon for oxygen. Added in small percentages, as low as 0.1 per cent. by weight, it is said that it reduces segregation and increases the solvent power of the steel for gases. When added in excessive amount it produces pipe. Ferrosilicon owes its value to its ability to remove the oxygen by forming readily fusible silicates with Ca and Fe, but in some cases SiO_2 remains in the steel because of its infusibility. In any event, ferrosilicon cannot be regarded as a substitute for ferromanganese.

Ferrotitanium Alloys.—Both ferrocarbon titanium and carbon-free ferrotitanium have found quite extensive application in steel works metallurgy in late years for the purpose of deoxidizing and denitrogenizing metal, but their warmest adherents or the companies manufacturing them do not suggest that they be used as substitute deoxidizers for ferromanganese.* They are regarded as so-called super-purifiers, and leading authorities seem agreed as to their beneficial effects. That the alloys have found favor in practice is recognized, because a large industry has been reared upon the production and sale of ferrocarbon titanium, and in another works ferrotitanium is one of the principal products. It appears difficult to incorporate titanium in steel as an alloying element, but the metal combines with nitrogen with very great avidity and is practically the only one which removes dissolved nitrogen in present-day work.

Other Deoxidizers.—Some of the other deoxidizers already mentioned have found a limited use; where they contain three or more elements in the alloy, these elements apparently augment one another's effects, but whether some of them are suitable or not is difficult to say. Whether they are or not, they have not enjoyed much use in modern practice.

5. THE USE OF LIQUID FERROMANGANESE.

In view of the utter dependability of steel makers upon foreign sources for their manganese supplies, it is little short of surprising that more time has not been spent upon the subject of substitute deoxidizers or even on the matter of conserving the available manganese supply. When spiegeleisen, the low-percentage manganese alloy, is melted in cupolas, the large clouds of red smoke constantly issuing from the cupola tops indicate the utter extravagance of such a method. For melting the high-percentage alloy, the cupola is totally out of consideration. Various furnaces, fired by coke, coal, gas, or oil, have been tried for melting manganese alloys for liquid addition without satisfactory results. The standard method of adding ferromanganese (*i.e.,* the high-percentage alloy) has been to break the alloy up into lumps and shovel it in in the solid state; in many European works the alloy is preheated red hot before adding. However, the experience of practice has shown the extravagance of this method also, because the loss in manganese totals from 20 to 35 per cent. from volatilization. If this could be recovered it would represent a yearly saving, in a plant making 300,000 tons of steel per annum, of about $26,000, figuring ferromanganese at $55 a ton. At the price paid for ferromanganese in the past two years, the saving would be a great deal more. Naturally, whether it would pay to make this saving would depend upon the cost of so doing.

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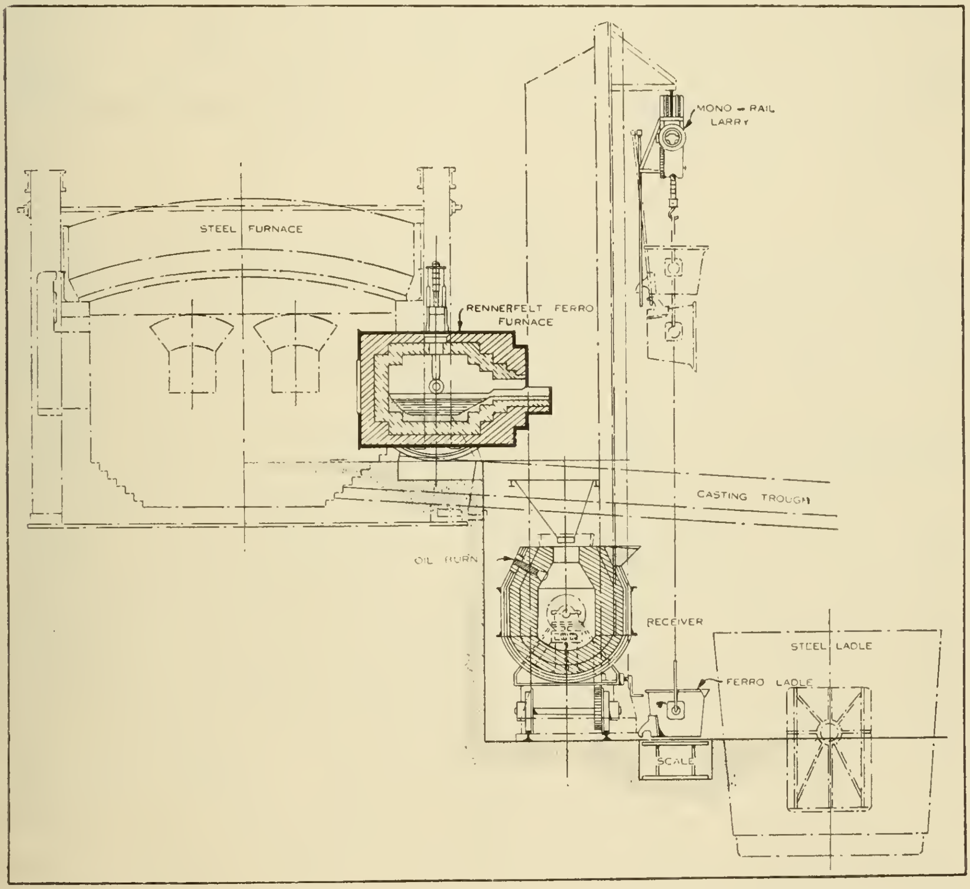
* NOTE.—In this connection, the work of W. A. Janssen, described in "The Use of Titanium in the Manufacture of Steel Castings," Cleveland meeting, 1916, American Foundrymen's Association, is interesting, as it represents the first recorded attempt to substitute ferrotitanium for ferromanganese in part.

Among others, Alex. Sahlin, of Brussels, has prominently pointed out how melting ferromanganese in the electric furnace is both practical and economical.[15] No practical method for melting was available until the advent of the electric furnace, but now a number of plants in Europe have installed ferromanganese melting furnaces. Heroult, Girod, Nathusius, and Keller arc furnaces, as well as the Roechling-Rodenhauser induction furnace,

FIG. 2.



Rennerfelt melting furnace and scheme for large plant making heavy heats. (After Sahlin.)

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[15] Sahlin, Alex., "The Use of Liquid Ferromanganese in the Steel Processes," *Jour. Iron and Steel Inst.*, 1914, No. 2, p. 213 *et seq.*

are used. The cost of electric current for operating constitutes the principal expense item. Irrespective of the working of the method, it is stated on good authority that worth-while savings can be effected, and those interested can refer to the account by Sahlin. The Rennerfelt furnace, brought out in 1913 by Ivar Rennerfelt, has proved particularly applicable for ferromanganese melting. Using this furnace, the layout in Fig. 2 is recommended for large steel works making heavy heats. Where high-grade or special steel is being made, and cost is a minor consideration, as in the manufacture of manganese steel castings,[16] the ferromanganese is melted in crucibles or in small, specially-designed reverberatory furnaces. This method of procedure would not do for general work.

6. RÉSUMÉ.

It appears, in the light of the facts presented in the foregoing, that the manganese situation is one of serious importance—one that warrants thoughtful consideration on the part of those interested in the subject. The possibility of metallurgical science discovering a substitute deoxidizer which will take the place of manganese, either in whole or in part, appears to be an alluring one. Naturally, any attempt at such an endeavor will call for a large amount of labor on the part of many men, and it is not to be supposed that the final solution of the problem will be effected in any short time. The matter of obtaining suitable coöperation with steel makers for the use of their plants so that experiments may be carried out on a scale commensurate with that of practice is one that will have to be taken care of by research men who hope to contribute in large measure to any progress along this line. Steel works laboratories have an opportunity before them, if they have not already grasped it—and they apparently have not, if published data can be any criterion. A recent investigation [17] carried out in this country appears to be the first well-defined attempt in this direction.

CLEVELAND, OHIO, February 21, 1917.

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[16] McKee, W. S., "Making Manganese Steel Castings," *Iron Trade Review,* February 15, 1917, p. 413 *et seq.,* from a paper at the Cleveland 1916 meeting of the American Foundrymen's Association.

[17] Boylston, H. M., "Investigation of the Relative Merits of Various Agents for the Deoxidation of Steel," Carnegie Scholarship Memoirs of the Iron and Steel Institute, vol. 7, 1916, p. 102.

THE PRODUCTION OF LIGHT BY ANIMALS.*

BY

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HISTOGENESIS AND PHYSIOLOGY OF THE LIGHT-TISSUES IN LAMPYRIDS.

As was said in the previous chapter, the fire-fly begins life by being all luminous, by showing a pale luminosity from all of the peripheral cytoplasm of its one-celled oösperm or egg. We do not know whether this power extends back into sperm or ovum or not. That sex has an influence on this secretion of luciferine granules is evidenced by the fact that the minute granules are round in the male and rod-shaped in the female when the adult organ is developed. During the resulting cleavage and differentiation of the fertilized ovum this power of secreting photogenin still persists.

Some writers have assumed that the pale light of the egg came from the yolk bodies, but it is a far better plan to assume that it is developed from granules of luciferine secreted from, and contained in, the cytoplasm of the ovum. Whether it would, under those circumstances, show as a brighter light in such parts of the cytoplasm as are most concentrated or not is a question that has not been studied by experiment or observation. On the other hand, it seems probable that it is confined to the ectosarc, which must be regarded as the most highly differentiated part of the organism even at this early period.

During the later cleavage and differentiation of the oösperm the light power appears to become segregated in a small group of cells that form the anlage of the future light-organ. The exact method of this segregation has not been studied closely, but R. Vogel has seen it in embryos of 18 days' incubation. He shows that it has some relation to the fat bodies and that it does not originate from an imaginal plate.

F. X. Williams has made what are probably the most complete studies on this question, although they leave much further study to be desired. He does not give us the age of the embryonic larva in which he was able to identify the developing light-organ, but

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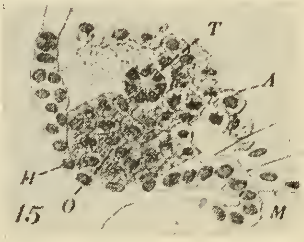
* Continued from page 348, vol. 183, March, 1917.

it was quite young, as can be seen from Fig. 1, which is copied from Williams's paper. In this stage (Fig. 1) the light-organ appears as a mass of polyhedral cells lying in each side of the eighth segment between its anterior end and its tracheal stigmata. The upper portion of the mass rests against cells that are forming the fat-body, and it is a fair question if these light-cells were derived from the fat-body or from the mesodermal cells that the fat-body also came from. The probability that it has been derived from fat tissue is much enhanced by the fact that its cells appear to form a series of stages that grade into the fat-cell type at the point of contact; also, the indeterminate cells on the border between fat-body and light-organ are multiplying by mitosis. On the ventral and lateral edge of this rudimentary organ it rests against the integument, which at this stage is composed of only the hypodermal layer of cells, no cuticle having as yet appeared. Here it rests in close contact with this epithelium and still is marked off from it by a distinct boundary. It appears almost as probable, but yet not quite so, that the light-cell mass was derived from this layer of epithelial cells as from the fat-cells.

FIG. 1.

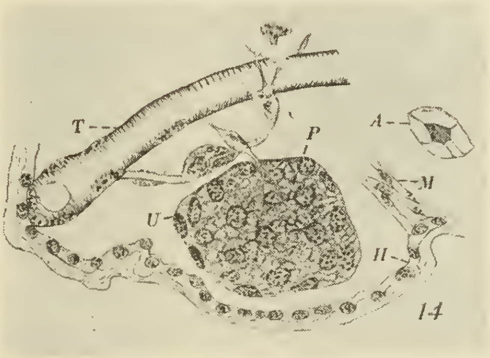


Section of developing light-organ in a young embryo of *Photuris pennsylvanica*. *O*, light-organ; *A*, fat-body; *H*, hypodermal epithelium; *T*, young tracheal tube. (After F. X. Williams.)

A tracheal branch is already coming to this embryonic organ and appears at *T*, although its invaginated cells have not yet secreted any cuticle, and therefore no lumen is as yet present. This immature organ is already giving forth light, and this raises some interesting questions. Has the light-producing power been entirely segregated in these cells, and, if so, was it an inheritance through the cytoplasm or the chromatin of the weakly luminous oösperm? In the first place, the embryonic anlage of the light-organ shows at all stages the power of lighting, and it probably carried this power with its constituent cells from the first cleavage.

But several other things have to be accounted for. They are, first, that a new light-organ will later be developed in the adult from cells that do not form a part of this larval organ, but from either fat-cells or hypodermis. Secondly, the germ-cells, either spermatozoa or ova or both, must carry the power to be developed in the next generation. Thirdly, Williams has observed that while in the pupal stage the thorax shows a diffused and moderately weak but definite glow, so that some cells in this region must also develop the photogenic power, even if only temporarily. These three kinds of cells, then, in the young fire-flies' bodies, outside of the regular light-organ, must all have the potential power of secreting luciferine at certain times in their history. It would therefore seem that they have an inherited tendency that only comes into operation at certain times in several varieties of tissues.

FIG. 2.



Section of developing light-organ in a somewhat older embryo of *Photuris pennsylvanica*. The organ has separated from hypodermis (*H*) and fat-body (not shown) and is now supplied with nerve and tracheal branches. The reflector layer (*U*) is beginning to differentiate from the luminous portion (*P*). (After F. X. Williams.)

We are reminded at this point of Peter's work on the Ctenophores. He found that the oösperms were not capable of lighting, but that after a very few cleavage divisions the embryos had acquired the power of emitting a flash of light. Later this power is confined to certain cells near the paddle plates, but Peters never found through which cleavage cells the power was transmitted.

The next step in the development of the larval organ that Williams saw is represented by his figure that has been copied as Fig. 2 of this work. The age of the embryo is not stated, but it had chitin and hairs well developed and was moving freely about within its egg. The organs were visible from without as two well-defined points of light shining through the shell. The development is far advanced in this stage from that seen in Fig. 1. The rounded mass of cells is clearly removed from any contact with the fat-body or with the hypodermis. Its cells show a very slight beginning of the differentiation into luminous and reflector layers. The strands of tracheal epithelium which appeared as thick heavy tubes with no definite lumen in the previous stage, where they had scarcely reached to the light-organ, are here formed of thin, distinctly flattened epithelial cells that have secreted the tracheal tubes of chitin, and these tubes now penetrate the light-organ and branch, to furnish it with its supply of air.

Where the light-organ measured only 17 × 21 micra in the previous stage, it now reaches a diameter of 24 × 34 micra. In its full grown larval form it measures 451 × 577 micra.

The above short sketch of the early development of the larval light-organ is practically all that we know. There still remain to be determined positively a number of facts and conditions, the most important of which is whether the organ is derived from the ectoderm (hypodermis) or mesoderm (fat-body); the conditions seem to point to the latter.

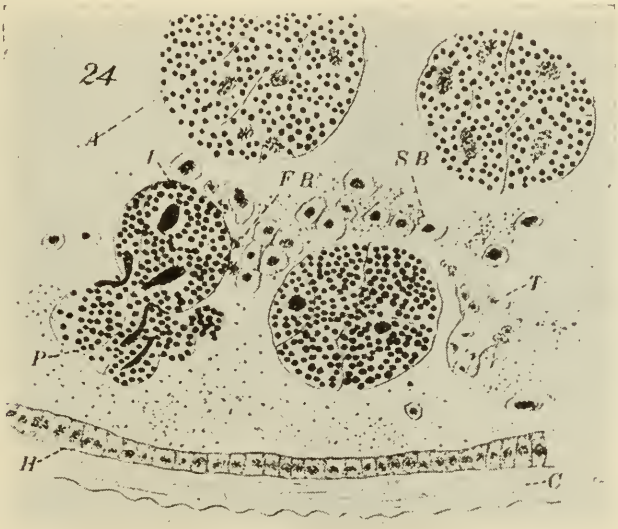
The development of additional lighting areas and tissues that takes place in the change during late larval life and the larger portion of the pupal life will next be discussed. The completed organs of the adult and their structure have already been describe in the preceding chapter; also, the fact that the thorax of the pupa shows a general glow, as has been described by McDermott, Williams, and Mr. Harry Parker. The writer has also noted it in some pupæ that were being raised in captivity. The exact source of this light should be further studied and an explanation sought.

The origin of the adult male and female abdominal organs has been often looked into in a superficial manner and many surmises made concerning it by many writers. Two chief theories concerning the subject exist: First, that these organs are derived from the ectoderm, or the hypodermal cells of the integument; second, that they are derived from the mesodermal tissues by a transformation of certain of the fat-body cells; thirdly, some writers have claimed that they are derived from both of the above sources, the reflector layer from the fat-body cells and the light-producing layer from the hypodermal cells.

Owsjannikow, Heinemann, Marchal, and Dubois have all come to the conclusion that the organ is derived from the hypodermis and the writer has found some evidence to show that it may be true. His studies are still being pursued.

Treviranus, Max Schultze, Emery, Leydig, Seaman, Wheeler, Bongardt, Berlese and Vogel, on the other hand, have understood that the fat-cells were the source of the photogenic tissues. The writer and W. A. Kepner have also published this view in a textbook, but solely from following some of the above writers. The best and most recent work on the subject is by F. X. Williams, who supports the idea from independent study. He expresses some small doubt, however, in his account.

FIG. 3.

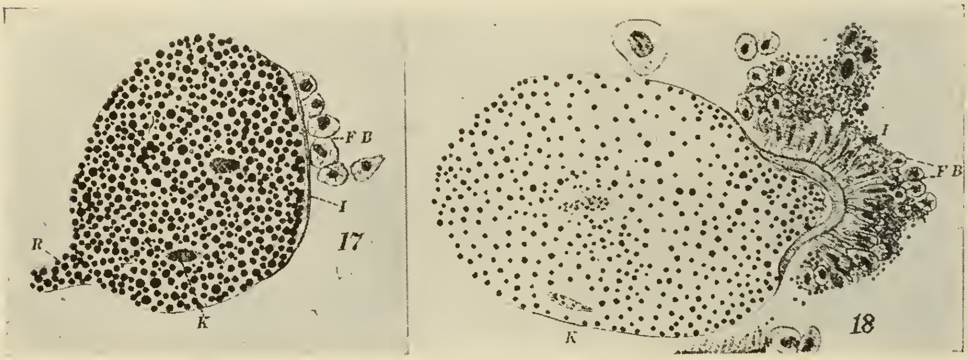


Section from the ventral abdominal region of sixth or seventh segment of a larva of *Photinus consanguineus* a few days before pupation. Two upper fat-bodies at *A*; also two photogenic fat-bodies (*P*), one of which is beginning to rupture and allow the photogenic fat-cells to emerge from its ventral surface. (After F. X. Williams.)

Gegenbaur is responsible for the third view. Others have expressed unusual and unfounded views which are clearly a mistake: Lindemann and von Kölliker, that it is a part of the nervous system; Pierantoni, that it is a symbiotic organ in which luminous bacteria live and produce the light, and Buchner, who had much the same view. At the present time we must accept F. X. Williams's work and take the view that the entire luminous organ is derived from the larval fat-bodies. He found the first evidences of the formation of the light-organ in a larva which outwardly showed no signs of being ready to pupate. Such signs appear several days before the change as a growing torpidity and the refusing of all food. The evidence consisted in a slight change in the appearance of the ventral fat-bodies of the sixth and seventh abdominal segments. This change consisted in a larger nucleus, a slightly deeper staining of the cytoplasmic contents, and in showing more distinct walls (Fig. 3).

The next stage is in a pupa (Williams does not state the time from pupation) and shows the growth or accumulation of a peculiar hyaline material on the dorsal surface of the fat-bodies destined to form the light-organ. In section this deposit is crescentic in shape and always on the dorsal side of the fat-body, which is made up of a number of fat-cells. A number of blood-cells become attached to this investment and grow in size. This is well shown in the two stages drawn in Fig. 4, where we can also see that the blood-cells accumulate a mass of small granules of some other substance around and between their bodies. This phenomenon is not peculiar to the photogenic fat-bodies alone, but to any fat-bodies that are undergoing rapid change, and may be seen in the thorax as well, where the hæmocytes also attach themselves to the mass.

FIG. 4.

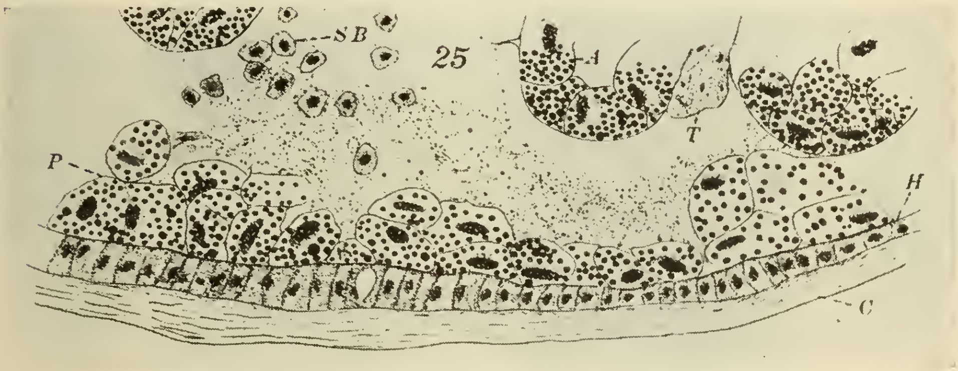


Two photogenic fat-bodies from pupating larva of *Photinus consanguineus*. Earlier stage (17) and later stage (18). *K*, nuclei of fat-cells; *L*, deposit or investment of hyaline material on dorsal surface of fat-body. *FB*, blood-cells which gather on investment. (After F. X. Williams.)

The next step is the application of some form of pressure, possibly a squeezing action by the investment, which results in the rupture of the ventral surface of the fat-body and the passage of its constituent cells out and down to the ventral hypodermis against which they lie. The squeezing, rupture of the wall of the fat-body, and the emission of the fat-cells are well shown at *P* in Fig. 3 from Williams. The resulting deposit of fat-cells on the ventral hypodermal layer is shown in Fig. 5.

The writer would like to know a little more about the manner and means by which the light-fat-cells move from the fat-bodies down to the position they now occupy. That they are squeezed out of the fat-bodies is apparent. Does gravity cause them to assume their ventral position? Probably not, since the metamorphosing larva and pupa frequently lies on its side. The experiment should be tried of forcing it to lie on its back during this stage and observing the result. The cells may have some powers of ameboid motion and attain their position by this means. They apparently move through a blood or body fluid with nothing or very little to guide them.

FIG. 5.

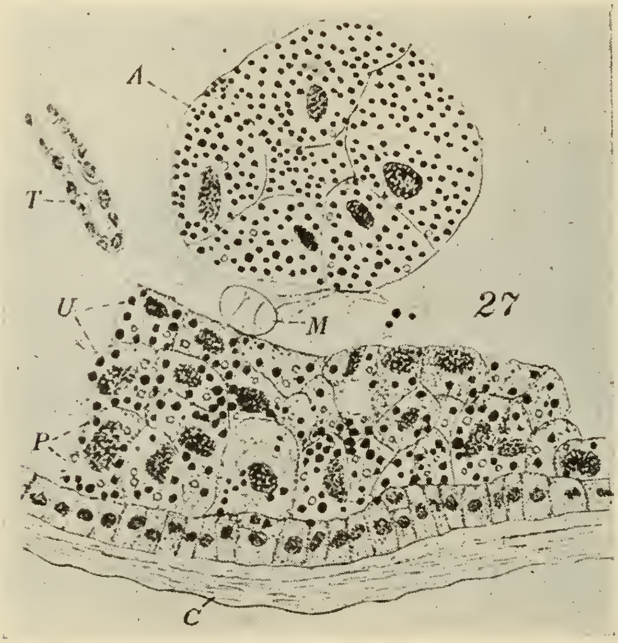


Transverse section of the ventral part of a light-segment of a pupa of *Photinus consanguineus*. *P* indicates the irregular layer of photogenic fat-cells that have been squeezed out of the photogenic fat-bodies and deposited on the ventral hypodermis; *C*, cuticle. (After F. X. Williams.)

When first in position they are somewhat irregularly distributed and still contain the characteristic round granules of albuminous material seen in other fat-cells. Vogel describes a breaking up of these large, rounded granules of reserve matter into the photogenic granules. Williams more correctly interprets the process as a solution of these bodies to form a general food that can be used in all building of tissues, including the photogenic granules.

A number of processes now go on together. The following sketch will outline them without giving exact times of each change with reference to the others. The future light-organ cells multiply in number and become arranged in a very regular layer instead of the more or less irregular one of the first stage. The ventral cells of the layer are first to dissolve their albuminous granules and also grow somewhat faster. Fig. 6 shows this condition after Williams. At this time the layer contains no tracheal supply, but the approaching distal ends of the tracheal channels may be seen advancing in the direction of the layer as tubes of thick, heavy cells in which the chitinous lumen is not yet developed (Fig. 6, *T*).

FIG. 6.

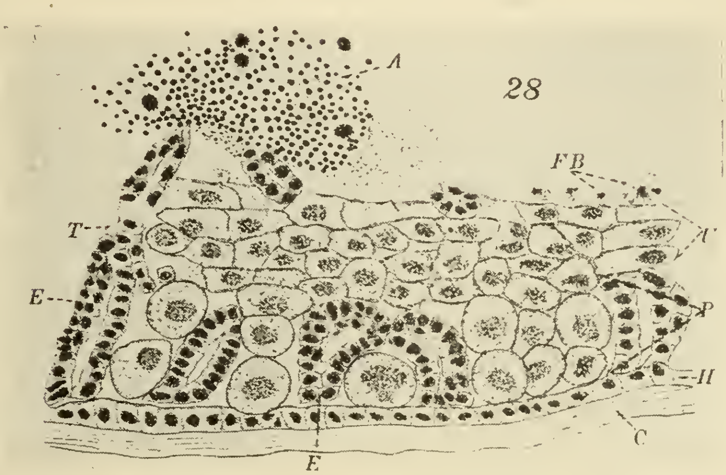


Transverse section of the ventral part of a light-segment of a pupa of *Photinus consanguineus*. Development advanced from section seen in Fig. 5. *T*, advancing tracheal tube; *A*, fat-body; *U*, reflector-cell layer; *P*, light-cell layer; *C*, cuticle. (After F. X. Williams.)

Fig. 7 shows a marked advance. The light-organ cells have all lost the reserve granules. The ventral layer shows cells that have advanced much in size and which are clearly becoming arranged to form the masses between which the " cylinders " will lie. Already the tracheal tubes have pushed through the upper layer which is to become the reflector layer, and now dip into the walls to form these cylinders. Their uniform epithelial walls will differentiate into ordinary flat tracheal cells and the specialized tracheal end cells that were described in the last chapter. As yet only an opening lumen and the beginning of the chitinous channel are visible.

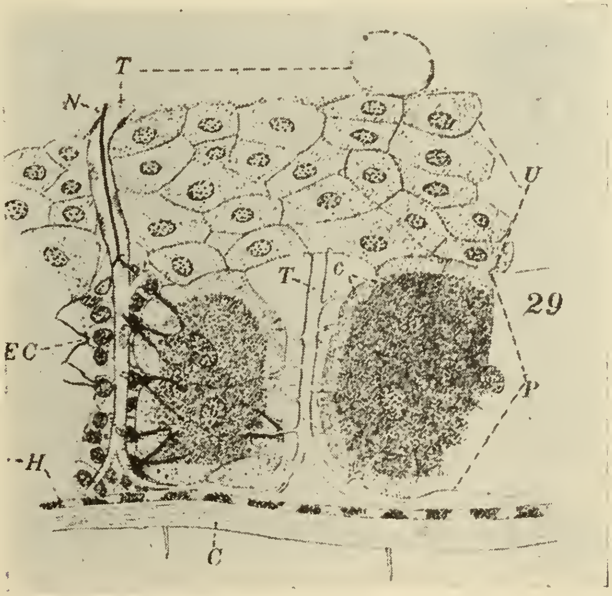
Fig. 8 shows what may be considered to be the completed

FIG. 7.



Transverse section of the ventral part of a light-segment of a pupa of *Photinus consanguineus*. Development advanced from that seen in Fig. 6. Reserve granules are all absorbed. Tracheal tubes (*T*) have penetrated light-organ to form beginning of cylinders. Letters same as in preceding figure. (After F. X. Williams.)

FIG. 8.



Transverse section of the ventral part of a light-segment of a pupa of *Photinus consanguineus*. Practically adult condition. *EC*, end-cells; *P*, light-cell layer; *N*, reflector layer; *T*, tracheal units. (After F. X. Williams.)

condition. Since it has been described before, any further description than its legend will be omitted here.

HABITS AND ECOLOGY.

The Lampyrids inhabit a great variety of situations. These localities must always be such as provide the proper food, and, in so far as we know, this food always consists of living snails or slugs. There is no form of migration so far as can be seen, and the larva probably lives all of its two years of life within a hundred yards of where it was hatched, while the adult male appears to fly in search of its mate for not over a quarter of a mile. Also, the female of most species is not so given to flying, and in some species is without that power. The writer knows of several colonies of *Photuris pennsylvanica* in the neighborhood of Princeton that are confined to areas of not over ten acres, and the larvæ are always found on this spot. During the breeding flight the insects sometimes fly a mile away, but usually fly in an irregular course over the locality itself.

The larvæ are nocturnal, as have been described for their feeding habits. The flight of the adult lasts for only a few weeks at the most, and they are not known to take any food during this whole time, their energies being devoted to mating and depositing the eggs in the proper position for the life of the future larvæ. As is true of the larvæ, the time of activity in the adult is in general the night-time. Some few forms are known to be on the wing in the daytime, even in bright sunlight at midday, as has been described by McDermott for a specimen of *Pyractomena angulata* that he captured in Washington, D. C.

Photinus scintillans has been watched for several seasons by the writer on his lawn at Princeton, N. J. This little fire-fly has a decided tinge of yellow or even orange in its flash. The males appear in latter June, at first a few stray specimens and a few days afterward great numbers, including some females, every evening. The first flashes are seen at about sunset or a little before, and these are in the grass. The insects may then be seen crawling up blades of grass, emitting the light at intervals, and, when they reach the top of the blade, flying off. At first they stay near the ground, but shortly after dark they fly at an increasingly higher level until, at 9 to 10 P.M., they are twenty feet or more up in the air. They then begin to fly irregularly and also to either stop flashing or retire to the ground for the night, for after that hour they are seen no more. They are said to come out again at dawn, but no observations as to this fact could be found.

The females of this species are wingless and therefore do not fly. They crawl up on a blade of grass and stay there, flashing until their mate finds them. After copulation, which lasts for some hours, they go to the ground and remain there, wandering around and laying an egg here and another there until all are exhausted. The number of eggs is small, about twenty, and they seem to be all fully grown and ready for laying when the insect first hatches. The female lays them among the grass roots.

Another species, *Photuris pennsylvanica,* much larger, begins to fly later in the evening, usually at 8 P.M., or later, and flies further into the night. Both sexes are on the wing, and their strong single or double flash of an intensely greenish-yellow color is visible from six feet above the ground up to as high as the highest trees of the forest on whose edge they fly. The writer has seen a few examples of this specis flash in the darkness just before dawn. While usually local, they sometimes wander far, and have been caught a mile or more away from their "colony" and flying about with *Photinus scintillans* on the campus at Princeton.

The mode of lighting in the adult insects is varied in all these forms. Most of the species have a characteristic flash, but besides this usual flash the light often appears in other forms of glow. The characteristic flash has been best described by McDermott in several papers, and has also been studied by Mast, Lund, Fisher, Barber, and others. It is well summarized by McDermott for eight species found around Washington, D. C., in the table shown as Fig. 9. Here the flash is represented by a curve on section paper in which the abcissæ indicate time (1 cm. represents 1 second) and the ordinates show the degree of brightness (1 cm. equals 0.02 candle-power). Also, we can note here that the flash of the male is in general shorter but more intense than that of the female. In one form there is an "after-glow" following the male's flash (*Pyractomena borealis*). In *P. angulata* the male gives a series of rapid flashes. In *P. lucifera* the male gives a succession of flashes that are so rapid that it forms a single pulsating flash. The female of this species answers with a single steady flash. A glance at the diagram (Fig. 9) will serve to show better than further description the kinds of flashes used.

In the last few years it has been decided by some zoologists that practically all these flashes are mating signals. This has been proved in several cases, but is not so easy a fact to observe as some might suppose. In fact, it seems that the flashing is sometimes done entirely at random; and while searching for the mate, of course, the flashing goes on in such a way that its relations cannot be understood.

FIG. 9.

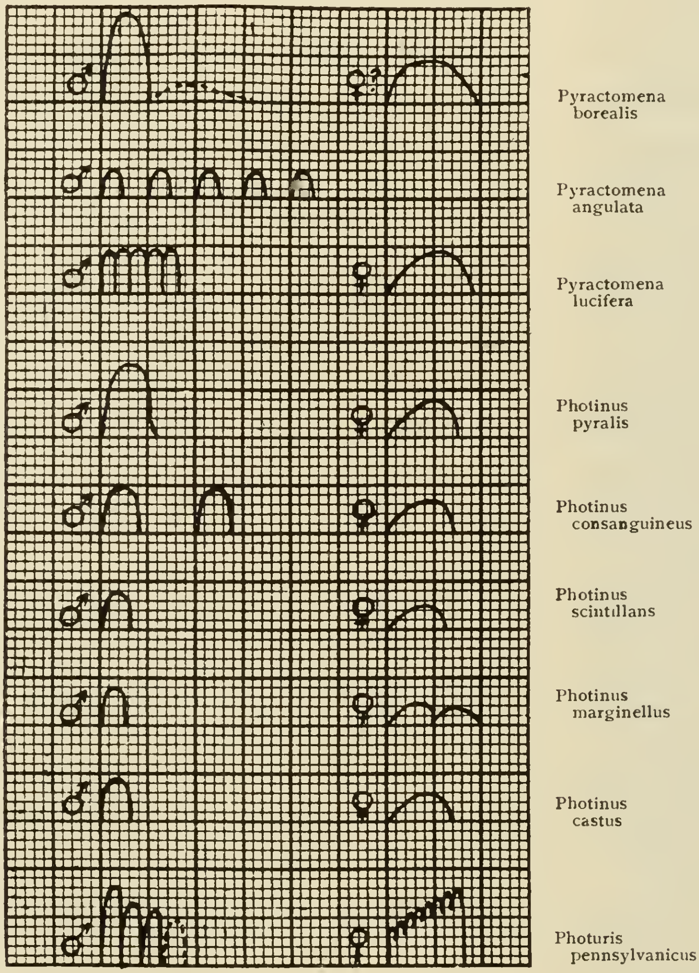


Chart to indicate the different forms of flashing used by males and females of several species of fire-flies. Distance from left to right equals time (one second to each centimetre). Distance from below upward equals intensity of light (0.02 candle-power for each centimetre). Male flashes to left, females to right. (After McDermott.)

The work of several observers, particularly McDermott and Mast, has shown that the flash of the female is used to attract the male, while that of the male is evidently to announce his presence. In some cases both male and female fly (*Photuris pennsylvanica*), and both sexes can be attracted to a small electric bulb, covered with a bit of thin green leaf and operated in a manner to simulate the light of the insect. Both sexes were attracted in this way and captured.

In other cases the female does not fly or cannot fly and sits on grass-blades or on the trunk of a tree and signals the male from there by her characteristic flash. McDermott has described this for *Pyractomena borealis* near Washington, D. C. Here the larvæ pupate in cracks in the bark of trees, and when hatched the female stays on the tree trunk and signals. The males answer her flash, and alighting upon the tree trunk, run about until they find her.

Mast observed a species found near Baltimore, Md., and was able to study the reactions easily. He found that they emerged and began to flash before it was dark and while one could still see well enough to read print. The females crawled up grass-blades and sat there without attempting to fly. The males flew about, flashing regularly at intervals of about five seconds. The females did not attempt to light unless first stimulated by the flash of a male near by or by a flash from some artificial source. When she did answer the flash of the male he turned and flew directly toward her. Several repeated flashes and answers were required to bring them together.

Mast decided that the flash was the only factor involved in this attraction, and that the male, no matter how near, was not drawn by either the objective sight of the female or by any odor. The writer disagrees with this in the case of *Photinus scintillans*, as he has confined them in a small vivarium and seen them come together and mate without any flashing when near enough.

Mast showed that the male is not positively phototropic to a continuous light, but only obeys a flash. The act of turning in a given direction and of flying toward the female, which he does with wonderful accuracy, is performed only a second after her flash has been seen, and is done in darkness and with no signal other than the former flash to guide him.

In certain other species the female gives off a continuous glow, to which the male, who flashes, is attracted. The best example of this is perhaps the European form, *Lamprohiza splendidula*, spoken of in the preceding section. The body of the female is very light in color, and her numerous lights, all glowing at once, cause the whole form of the insect to shine so that the individual organs can hardly be distinguished. She crawls slowly about or lies quietly in some damp corner in the grass, and one can look over a hillside and count the individuals so lighting for several hundred yards about.

It is not always possible to definitely get a reaction by artificial means to prove this use of the light as a sex lure, nor to establish the fact from carefully watching the insects in flight. The fact had been established for *Photuris pennsylvanica* by Mast and McDermott, but the writer once went out to observe this with Dr. S. O. Mast at Beaufort, N. C., and, although hundreds of this species were flying about and both males and females were caught, the attraction lighting could not be observed Nor could any of the insects be lured with the flash of the electric hand torch. McDermott found that the light had to be shaded with a bit of green leaf or other green transparency; or, even by shading the light with the hand, the males would approach it, although the color was then reddish instead of greenish. It thus seems that the color of the light was not so important as its intensity and time.

Another factor observed in the case of *Photinus scintillans* was that of the time between flashes. Here, too, the color was altered by interposing screens of glass stained in various ways, and yet no difference appeared in the reactions. On the other hand, if the flash was timed properly, a factor that varied with the temperature of the air, the males could be lured by an electric lamp or even by striking a small match. This would not seem to be the important factor when one remembers that the light color varies in the different species.

Other methods of flashing have been observed. McDermott describes four distinct methods of flashing for *Photuris pennsylvanica,* and his observations are quoted as follows:

"Four distinct types of light-emission on the part of this species were observed, agreeing with those previously reported (*Can. Ent.,* 1910, vol. 42, pp. 358–360). First noted was a series of usually three, though sometimes four or five, rapidly repeated flashes of considerable intensity, followed by darkness for several seconds; the flashing thus was repeated at intervals of from not more than three seconds to as much as half a minute. The series of flashes is suggestive of that of the male of *Pyractomena lucifera*, except that ordinarily not as many separate flashes are given, that there is a distinct interval of darkness between succeeding flashes in the series, and that the flashes in any series appear to be of diminishing intensity" (see diagram, Fig. 9). "The specimens which exhibited this type of flash came to the lamp when given the long flash described, and were *usually, though not always,* found to be males.

"The second type of lighting observed was that which the writer has previously described as 'a faint glow, rapidly increasing in brilliancy. . . . It then ends suddenly.' . . . The only correction to make on this earlier observation is that this flash, when observed close at hand, is seen not to be a continuous steady flash, but a series of very rapid pulsations, or a flash of very rapid variations in intensity, such as may be observed in a moving mirror image of an arc-lamp operation on an alternating current (see diagram). As compared with the phenomenon of the alternating-current arc-lamp, 'frequency' appeared to be about 50 per second, rather slower than the lamp (60 cycles). One insect flashing thus was caught on the evening of May 27 and found to be a female, but at this time none could be attracted to the electric light by imitating either this flash or that described in the preceding paragraph for the male. Later, notably on the evening of June 17, along the Chesapeake and Potomac Canal, only a few hundred yards from where the first observations were made, females giving this long flash repeatedly came to electric lights operated in the flashing manner of the male, when used both by the writer and by Mr. H. S. Barber, the bulbs in both cases being shielded by a leaf. The reverse attraction, as described in the foregoing paragraph, was also observed at this time, and had previously been observed by Mr. Barber and the writer, along the canal on the evening of June 3. There were, however, some curious exceptions: for instance, on the evening of June 5, at the writer's residence, 1901 Jackson Street, N. E., this city (Washington), an insect giving the long flash was attracted to a lamp giving the flashing light, and when captured proved to be a male; also on the evening of June 13, at the same place, seeing the electric lamp giving a long flash, two females and four males were attracted, caught and identified. It was not found necessary that either sex be flying to respond: insects at rest on leaves and fences repeatedly responded by flashing to stimulation with the electric lamp and would sometimes leave their locations and fly to the light. Good results were never obtained unless the light was either shielded with a leaf or the bulb coated with a solution of malachite green and chlorophyll in collodion.

" The third method of lighting observed for this species was that already described as single, not very bright flashes, emitted at intervals of a second or two while the insect is flying through the air in almost any direction, dropping from a tree or running around on the ground or on the grass. In every instance these insects were found to be females. Operating the electric light in imitation of this flash did not seem to cause attraction of either sex, but in one instance, when a male was observed on a fence-rail, giving his usual triple flash, and responding to the electric-light flashes in imitation of the usual long flash of the female, the change to the type of flash above described caused him immediately to cease to respond. Provisionally we may regard this as the flash of a pregnant (or hungry) female.

" The fourth type of light-emission consists of a single, short, bright flash, repeated at intervals of about four seconds or more. This flash is the least common, and insects flashing thus were found to be males, and did not respond satisfactorily to the electric light."

In addition to the flashing as mentioned, we find cases in which fire-flies are said to flash in unison over a wide area. One writer describes a large field in which thousands of them flashed synchronously and rhythmically for a long period. Critics of this observation said that some such rhythm was apt to develop on the mathematical basis of probability and chance in any medium large grouping of such individual phenomena. The observation seems to have been confirmed, however, and established as an occasional fact. Prof. Henry Jones Ford related to the writer his observations of some tropical fire-flies seen along the Cotabato River, in Mindanao, Philippine Islands, one night in April. These insects congregated in a few isolated trees of a certain unknown variety and were found only in such trees. They seemed innumerable in each tree as it was passed in the night by the river steamer, and they were all flashing rhythmically and in unison.

There are other and abnormal methods of lighting commonly seen in the flashing varieties of fire-flies. Whenever one is captured by a spider or in a spider-net, it at once turns on the steady, somewhat weak glow that one sees in the larva. This emanates from the adult organ, the same that is used at other times for flashing. This same steady glow also shows as a trace or after-glow, coming immediately after the flash in the male of *Pyractomena borealis.* It may also be produced by administering various drugs or by injuring the animal seriously.

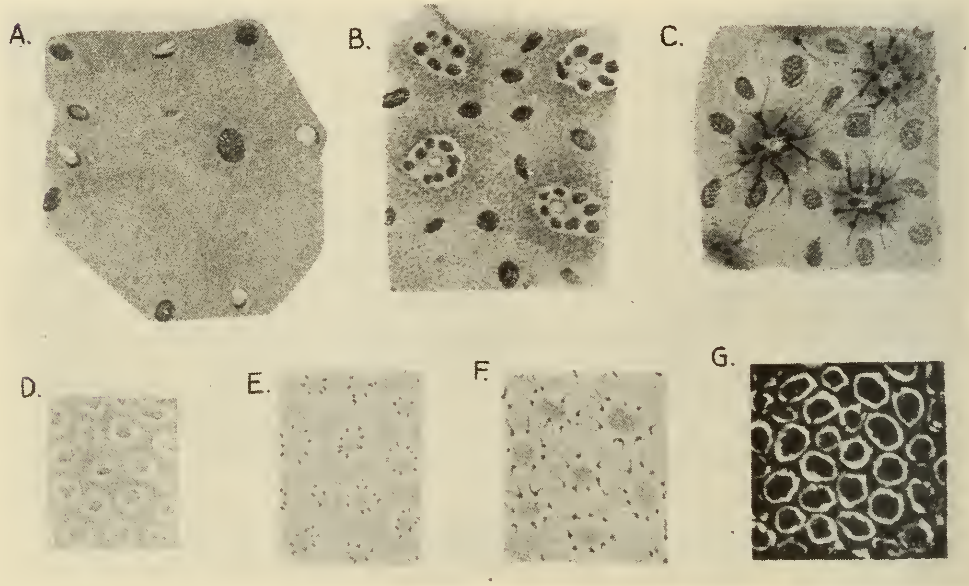
LOCALIZATION OF THE LIGHT IN THE ORGAN.

On casually observing the light from the organs of fire-flies one has the impression of a uniform, steady glow from all parts of the outer surface of this organ. And this idea seems to be true of the organ in certain species and in the larval organs; also, it is true of the light-organs of the elaterid beetle, *Pyrophorus.* Certainly all of the light-cells glow together (except in certain pathological cases), although all regions of each cell may not give off the same amount of light. This uniform glow of the entire organ surface may be said to be characteristic of not only the elaterids but of the larvæ of all Lampyrids and Phengodes. The reason of the steady, long-continued glow is a less perfect control, so far as speed is concerned, of the admission of air to the light-tissues, and this, in turn, is due to the lack of highly-developed end-cells on the tracheal twigs. The same condition is true of some adult Lampyrids which emit the light as a steady and more or less continuous illumination. The females of *Lamprohiza splendidula* and all species of *Phengodes* are good examples of this condition.

On the other hand, we find many adult Lampyrids in which, as is described on another page, the light appears in short, quick flashes. If such an insect is looked at casually while lighting it appears as if the light came from the entire surface of the organ, but if one examines this surface more closely, especially with a low-power microscope or a hand-lens, it is at once seen that the luminous areas consist of a series of circles. Emery and Lund have well described this, and Fig. 10, A, is copied from Emery's paper on the subject. In this figure the lighted surface (*G*) is compared with sections of the organ fixed and stained in various ways, and we can see that the rings of light correspond with the edges of the luminous tissue where it is in contact with the end-cells. *G* represents the beginning of a flash or of a weak glow of light. When the glow is stronger or at the height of the flash the outer limits of each ring are extended as the oxygen comes in through the tracheoles and penetrates deeper into the masses of light-cells, until, during a strong illumination, we see a luminous field with circular areas that remain unlighted or only partly lighted by reflected light.

In some few flashing forms, such as the Japanese species *Luciola vitticollis* and *Luciola parva*, we do not see any such circles, because the cylinders are not present.

FIG. 10, A–F.

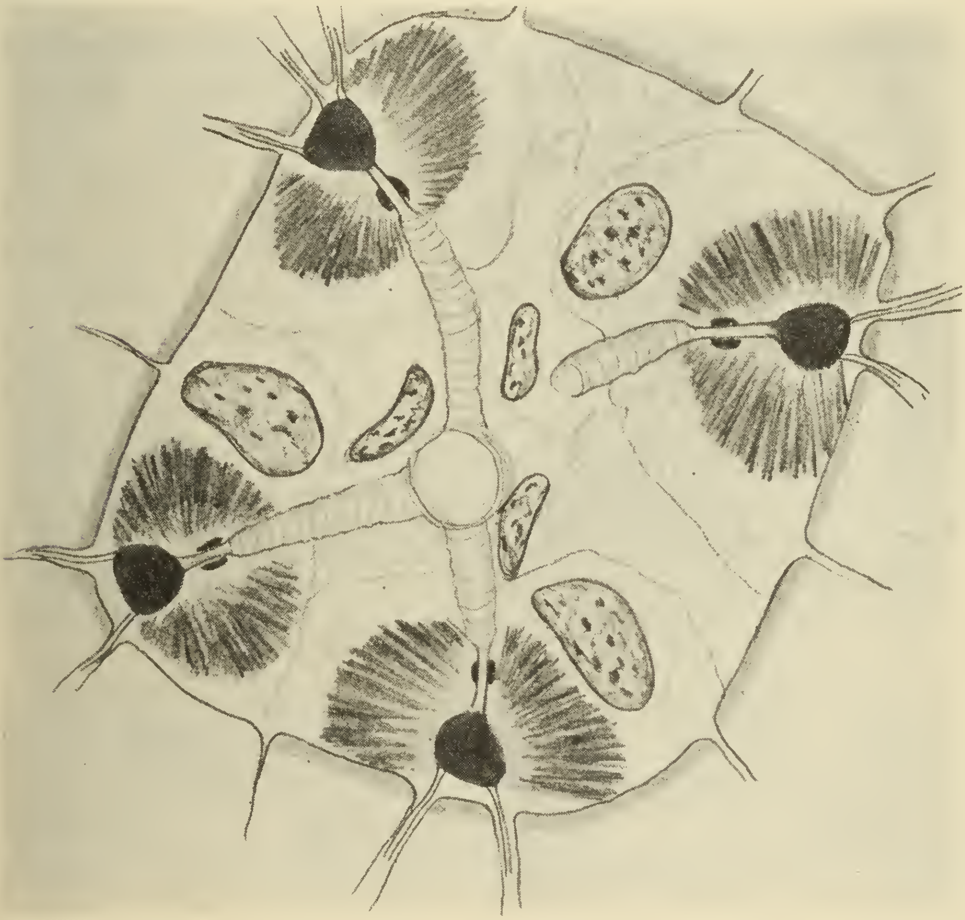


A–F, Figures of horizontal sections of light-organs of *Luciola italica* to show results of various methods of fixation and staining. *G*, view of surface of organ of same insect to show rings of lighting. (After Carlo Emery.)

Lund further localized the light as beginning in the regions of luminous cells lying in the angles formed by the branching of the tracheoles as they emerge from the end-cells. These points of light immediately spread to form the circles, and then the circles' enlarged and diffused light acted to render the whole surface uniformly bright.

If a fire-fly is cut in two or the last segments bearing the light-organ are clipped off with a pair of scissors, there is a flash, a glow, and then the organ gets dark. If we now raise the temperature slowly, a weak glow begins to appear at about 125° F., and this grows brighter until at near 190° F. the light suddenly dies out. In order to understand the immediate physiology that underlies these different kinds of flashes we must refer briefly to certain features of the structure of the organ. The masses of light-cells containing the granules of photogenin are supplied on most of their surfaces with tracheal end-cells that give off fine

FIG. 11.



Portion of a horizontal section of the light-cell layer of *Photinus consanguineus*. Shows one cylinder containing a tracheal unit in cross-section and four end-cells, edges only of the light-cells shown. Three of the end-cells show their large nuclei. Three tracheal epithelial nuclei also appear. Note the radial bodies, the small cylinder bodies, and the large distal rounded bodies from which the tracheoles emerge. These latter are only shown for a short part of their length as they pass between the light-cells. (Original drawing.)

tracheal capillaries which penetrate to all portions of the mass. These tracheoles, in *Photinus consanguineus* at least, pass between the cells. Air is supplied by tracheal stems that carry it from the larger trachea to which it comes from the stigmata opening from the outside edges of the segments. It is evident that the tracheal end-cells are the key to an understanding of the process.

Fig. 20 in the preceding part of this work shows the structure of one of these end-cells in *Photonus marginellus*, and Fig. 11 of this part is another and perhaps a better figure to show the end-cells in correctly-fixed and stained horizontal sections of the light-organ of the fire-fly *Photinus consanguineus*. Here it may be seen that the tracheal twig enters the cell and, having contracted to a very narrow tube, it ends in a cylindrical organ, from which two or more of the tracheoles are given off. The end-cell bears in the larger part of its distal body a peculiar specialization consisting of rods of a denser material that radiate from the end-organ of the tracheal twig; also, a rounded and still denser mass of a similar material that embraces the tracheoles just after they leave the end-organ. It is believed by the writer that these radiating rods and the rounded mass represent muscular structures which are of two possible uses: First, to prevent the passage of air into the tracheole by compressing them; this would appear to be the function of the rounded mass; second, to enlarge the terminal twig and end-organ and thus fill it with a new supply of air; this would seem to be a possible function of the radiating rods. It can be seen that a rapid alternation of the two actions would result in the forcing of a sudden jet of air bearing free oxygen into the light-cell mass and would account for the power of flashing as exhibited by the organ.

Geipel has shown that each end-cell is supplied by a branch of nerve-fibre (Fig. 22 in last chapter), and this would put the whole number of end-cells in the whole organ under direct control of some centre in the nervous system. We need further studies to show what this centre is, how the nerve terminates in the end-cell, and just what kind of contractile material the radiating rods and heavy mass that surrounds the bases of the tracheoles are composed of. It seems probable that two sorts of nerve supply are needed to account for the various operations of the organ: one to open the terminal twig and fill it with air, and another to compress the rounded body or constrictor and force a jet of air into contact with all light cells.

We would then be in a position to explain the steady glow that comes under abnormal conditions. When captured or injured the muscles would all be relaxed and a steady glow would result from the slow and steady invasion of air; also, when the excised abdomen was heated, the muscular control would be relaxed and the same result be attained. We know that the end-cells of the larva and of some allied forms do not show these muscle-like structures and can thus explain the steady glow and lack of flashing power that they exhibit.

In further reading and assembling the facts concerning the manner of lighting of fire-flies and the conditions under which the light may appear we find some difficulty in considering whether the results obtained and observed are due to physiological factors of nerve-muscle action and mechanical factors or to purely chemical factors by which the light is produced. It seems possible to separate them fairly well through a careful study of the experimental work of many writers, particularly that of Pfluger, Macaire, Bellesme, Kölliker, Heinemann, Dubois, Bongardt, Carradori, Watasi, Townsend, Kastle, McDermott, Lund, and E. N. Harvey. Such a review will reveal many possibilities as to future profitable experiment and observations. It will be best to first separate out the factors which appear to be purely physiological so far as possible, and reserve the more strictly chemical side for the chapter in the general chemical discussion of all the organisms which will follow. It is unavoidable that the two subjects should be somewhat entangled, however.

MECHANICAL.

We have already seen how the injury of the fire-fly will cause the light-organ to glow. Kastle and McDermott have described it and shown that the organ at once flashes and then slowly becomes dark. If the light-centre is in the brain, the flash would be explained by a sudden removal of the nervous inhibition which causes the muscle mass to contract violently, force air through the tracheoles and into the light-organ; the following darkness would also be explained by the lack of motor supply to again open up the end-cell terminal organ and admit a nerve supply.

Several authors have now shown that if the decapitated animal is allowed to rest it recovers from something (shock?), and if stimulated mechanically the organ begins to glow steadily again, perhaps over its entire surface or perhaps only on a part of this surface, depending somewhat on the nature and extent of the stimulus applied. Such stimulus undoubtedly acts on the organ through its nerve supply, and there must be a motor-centre in one or more of the lower ganglia through which the action takes place. McDermott found that such slight stimuli as tapping with a pin or match-stick or dropping to the floor would cause the quiescent organ to glow. Undoubtedly these very slight mechanical shocks worked through the nervous supply. In these cases the organ had been clipped off just anteriorly to its margin, so the motor ganglia were probably in the abdominal region.

While the above instances were cases that had no abnormal relation to the chemistry of the processes, there are others that have. If the light tissues themselves are cut or torn, air is admitted directly to the cells and we see a steady glow. This glow persists for a time and slowly dies out, owing to the fact that the exposed surfaces are exhausted and they then protect inner and unexposed parts from a further penetration of the oxygen. The ultimate case is when the organ is crushed and smeared between the fingers. Even then certain parts of the mass remain protected by outer artificial surfaces. If the crushed organ is again smeared between thumb and fingers it again glows, since new and unexhausted parts are exposed. The organ can be exhausted in an unwounded insect, as was shown by Tilesius and Meyen, by repeated mechanical stimuli. In this case two factors enter. First, the muscles (end-cell fibrils) that control the air flow may become fatigued, or secondly, either of the light-producing substances may be exhausted, either permanently or for the time being. The former is probably true in most of the experiments that have been tried. It would probably take a long time to exhaust the luciferine or luciferase (photogenin or photophelein). McDermott states, however, that a detached organ that cannot be made to light by simple percussion cannot be made to light in any other way.

TEMPERATURE.

When higher temperatures are applied to a decapitated insect or excised organ that is quiescent the light will appear and the organs begin to glow. Macaire observed that the light was extinguished above 52° C. and under 12.5° C. His experiments showed that the light which was extinguished under 12.5° C. reappeared at 27.5° C., and at 41.3° C. it was strongest. When it was raised to 57.5° C. it went out again, and if it continued to raise to 63° C. it could not be restored. The first part of these experiments has to do with nerve and muscle activity, while the last experiment shows (as Harvey's work bears out) that one of the two chemical substances was destroyed. The other will resist still higher temperatures and operate again when the other is supplied.

ELECTRICITY.

Electric shock will cause a living fire-fly to glow or flash, and work has been done on this line by Macaire, Jausset de Bellesme, Kölliker, and others. The shock applied to the living animal results in a flash or glow, according to the particular nerve-centre that has been stimulated.

Such electric stimulation has no effect whatever upon the chemical processes in the light-cells themselves, apart from the above stimulation through the nerve control. Experiments by E. N. Harvey have shown this conclusively, especially on organs in which the tissues have been killed by drying, thus separating the light materials from their influence entirely. Macaire also observed that so long as the tissues lived the electric current caused them to glow, but that the moment they were dead (as evidenced by an opaque color due to proteid coagulation) the effect stopped. Pfluger found that the electric spark would evoke the light in a living animal, but that the continuous current would not except at the make-and-break of this current.

PRESSURE OF AIR OR OXYGEN.

All investigators from Boyle down have found that, when placed in a vacuum or in hydrogen gas or some gas other than one bearing free oxygen, all attempts to evoke light from living or dead fire-flies was a failure, and that when the air or some free oxygen was then readmitted the lighting power was resumed.

Besides stimulating the organ through its nerve supply, Lund experimented with air pressure. He first applied direct pressure to the body in an unwounded insect and obtained a flash. This might have meant either a mechanical supply of air or a stimulation through nerve supply. He then cut off the organ and placed it in a sealed tube to which a moderate sized rubber bulb was attached so as to force air into the tube by a pressure of the hand. When the organ was quiet and inert he squeezed the bulb and obtained a flash or glow in some proportion to the pressure. This indicates that air was actually forced from the trachea into the light tissues. Such an artificial flash is almost as bright as the natural one. The same fact held true when portions of the organ were experimented with in the tube.

Lund points out that this phenomenon is partly controlled by another factor. Pressure applied as above may drive some air into the tracheoles, but it also increases the oxygen concentration and in that way makes the light brighter. The presence of free oxygen is a *sine qua non* of the reaction. More work on this subject is needed but will be difficult.

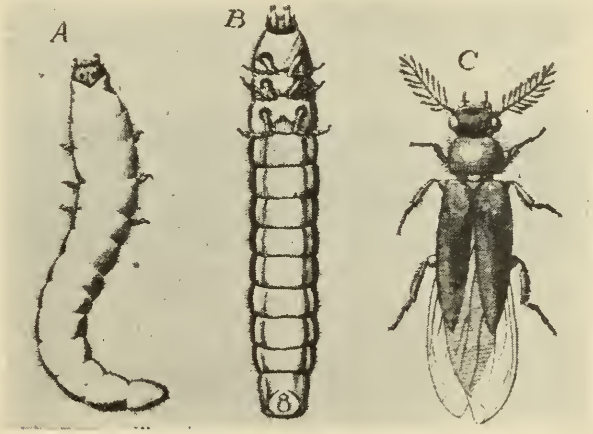
The chemistry of the light-process has been studied by a number of writers, the latest and most careful of whom are Dubois, Lund, McDermott, and E. N. Harvey. While a further and complete account of the reactions will be given under the chapter on the general chemistry of light production, we may sum up here a few of the principal facts. The granules of light-producing substance (luciferine of Dubois) are found in the light-cells of the organ. Harvey has called these granules photogenin. They are quite soluble in water in the fresh condition, but when coagulated by fixatives, become insoluble; they are doubtless much changed by the fixation. When in solution the substance is fairly stable. It is destroyed or changed so that it will no longer light after being exposed to a temperature of 42° C. It is not soluble in ether nor any of the fat-dissolving fluids. There is a larger amount of it in the body than of the assisting medium, called by implication luciferase (Dubois) in the fire-fly and renamed photophelein by Harvey on account of important mistakes which Dubois made while describing the light-producing substances in Pholas dactylus. Thus we can isolate or free photogenin from photophelein by allowing the two to react on one another in a free aqueous mixture. Under these circumstances the photophelein is exhausted and we have a surplus or residue of photogenin left with which to work.

The photophelein is probably in a fluid form and is found all through the tissues of the body. It is also found, or something like it, all through the tissues of the body of other, non-luminous insects or even other groups of animals, so it is not for use with photogenin alone, but produces other vital reactions in the body of the fire-fly, in all probability. The problem of the exact nature of these two substances, the proteid-like photogenin and oxidase-like photophelein, and how they operate, together with oxygen in the presence of water to produce so efficient light, is one of the most attractive problems in biology.

PHENGODES.

Allied to the Lampyrids, and by some included in the group, are a number of beetles that give light from a large number of organs and show a female of very primitive adult development. These insects are found in both North and South America and are not abundant in any locality. In many cases we know only the male or the female and can connect neither of them with the other sex or with the larval stage. In a forthcoming paper Mr. Barber, of the U. S. Bureau of Entomology, will give us the latest *résumé* of the groups with what is known of their structures and habits.

FIG. 12.



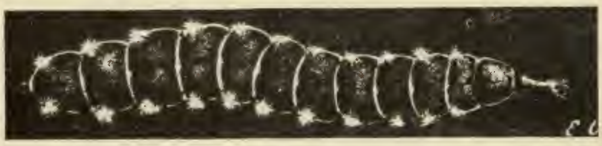
Larva (*A*), adult female (*B*), and adult male of *Phengodes laticollis*. (After Henneguy.)

Of the North American, species the best known, perhaps, is *Phengodes laticollis,* found near the eastern coast from Massachusetts to the South. Fig. 12 shows the adult male and female and the larva as pictured by Henneguy. *Phengodes longicornis,* Barber, is another eastern species which is perhaps not so rare. The males of these forms are said to give no light, while the females and larvæ, which resemble each other superficially, are among our most brilliant forms, giving off a bright greenish light from eleven of their segments, one organ on each side of the segment, or twenty-two in all.

A few of these insects are captured each year by entomologists, but they are unknown to the majority of those interested in natural history. Their luminous organs remain undescribed, but they probably resemble those of the lampyrids to a large extent. The larvæ and the apterous females hide under stones and boards, but on warm, wet nights in the breeding season (June) the females emerge and display their light to attract the males. The males fly and have large, keen eyes with which to find the lighted females. This method of seeking each other reminds one much of the habits of *Lampyris splendidula* of Europe as described on a preceding page. Fig. 13 shows the position and appearance of the lights on the illuminated female of *Phengodes laticollis* as shown by Henneguy.

Besides the North American species, those in South America are much more numerous and of perhaps greater interest on account of the color of the lights. We have quite a history, although an imperfect one, of their discovery and study. Azara, in 1809, describes a larva from Paraguay from whose sides rows of light shone, while from the head a red light like a glowing coal was seen to appear. Reinhardt, in 1854, made the same observation, securing his specimen from a bit of rotting wood in Lagoa Santa. The side lights were greenish and intermittent, while the red light was more constant. The larva was 40 millimetres long and appears to have been the apterous female. Its predatory nature was indicated by its formidable mandibles like pincers.

FIG. 13.



Appearance of adult female of *Phengodes laticollis* when she is using her light-organs. (After Henneguy.)

A. Murray, in 1868, described to the Linnæan Society in London a similar larva which he named *Astraptor illuminator*. This was probably another species of the same genus. Fry described another specimen from Rio de Janeiro. Agilvia described another specimen from Montevideo that was two inches long.

The well-known entomologist, Burmeister, in 1875, described the same sort of insect from Parana, in Argentina, in the month of August. This also showed the red and green lights and was undoubtedly one of the same genus, if not species. It was found in rotted wood in a forest. It was very lively and aggressive and fought its captor. In December, 1870, Weyenbergh found one of these creatures in a street of Cordoba (Argentina), in the evening, during a heavy rain. He described the side lights as bluish-white and the head light as bright red. Since he described various brown lines and spots on its back, this was probably an adult female. Dr. von Ihring also described one two inches long from Rio Grande de Sol, in Brazil; also, Dr. Alphons Stübel, of Dresden, collected one from Popayan, at an elevation of 2500 metres.

Several other writers have described elongate larvæ with side lights which seem to belong to one of the many species of *Pyrophorus*. There may be, of course, larvæ of Phengodes in South America that lack the red head light, but those from the southern parts of the continent always appear to have it and to be members of the genus Phengodes. Dr. Erich Haase, of Dresden, was so fortunate as to find a pair in copulation and to secure eggs from the female. These eggs hatched and the resulting larvæ lived for eighteen days. Dr. Hieronymus also found such a pair in Cordoba, and thus we are able to describe and know the forms of at least one species, which Haase named *Phengodes hieronymii*. The young larvæ had the greenish side lights and also the red head light, and the female was apterous and with the same lights as the larvæ, which she much resembled. The eggs were light-brown, and round, with a diameter of almost two millimetres, and were not luminous.

The male had light-organs on his ventral posterior abdomen, so here we find a Phengodes species whose male can illuminate. The female and the larvæ all had the characteristic greenish side lights and red head lights, even as the latter emerged from the egg. Besides the many Phengodes species, there are allied forms in South America belonging to another genus *Zarhipis*.

BRYOZOA.

We have as yet only uncertain reports of luminosity in Bryozoöns. In some cases the light has been traced to microscopic organisms that infested them, much as has already been shown to be the case for certain sponges.

There still remain reports, however, which should be followed up by careful research, by Molisch (*Membranipora pilosa*), Landsborough (*Flustra pilosa, F. membranacea*), Ehrenberg (a *Retepora*), and Gadean de Kerville (*Scrupocellaria reptans*).

Landsborough's work seems to be a reliable bit of somewhat superficial observation. He took leaves of the sea-weed *Fucus serratus* into the house and, noticing that they sparkled when touched, he tried to locate the flashes. These appeared to emanate from the tiny zoöphytes that are so commonly found on these leaves, and among them was *Flustra pilosa* and *F. membranacea*, as well as many hydroids. When shaken, the polyps gave off much light from all over their heads and stems. This light clung to the hand, indicating an external discharge. It also appeared to come from as many points on the surface as there were cells, as he puts it.

In favor of there being an autogenous light in these forms is the fact that it appeared upon stimulation and was given off; also, that it came from head as well as stem. Then, too, so many of these small marine forms possess the power. Against it is the fact that such organisms are always found to have hundreds of bacteria and protozoa as well as diatoms growing on their stems (but seldom on the head). Bacteria, of course, would shine steadily, while the one-celled protozoa and diatoms would respond to stimulation by a flash as seen. On the whole, it seems probable that the observation will prove to have been correct, although not carried out in a proper scientific manner.

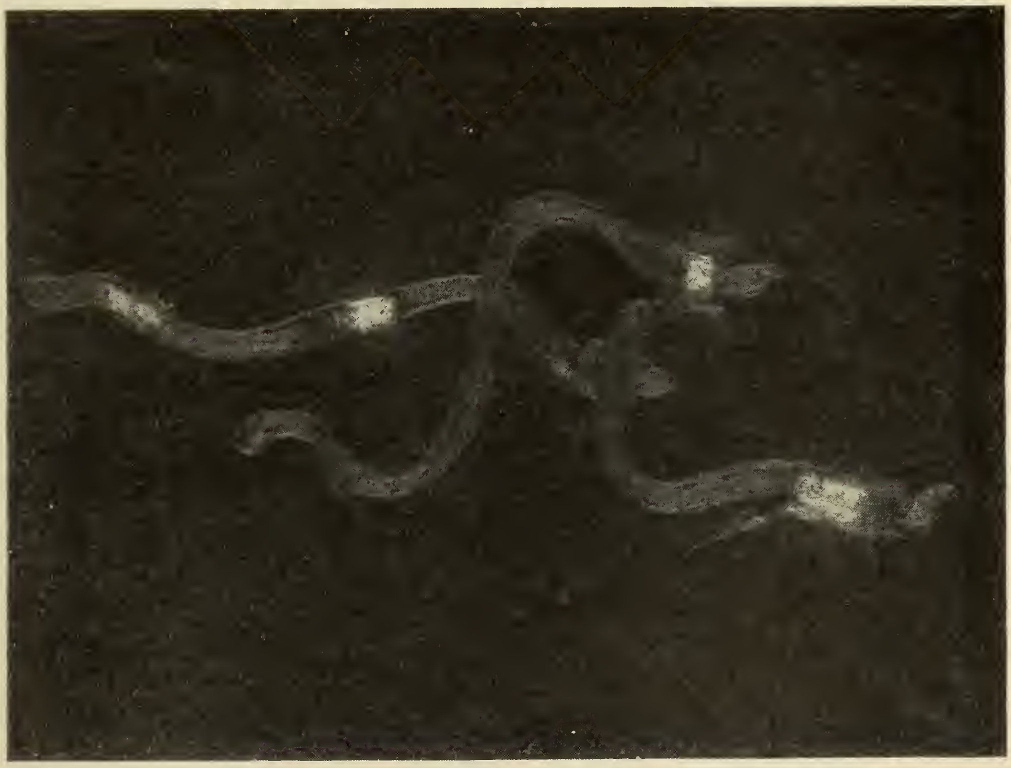
ENTEROPNENSTA.

The great photozoölogist, Panceri, was the first to discover that some of the species of *Balanoglossus* lighted. He first saw the phenomenon in *Balanoglossus minutus* at Naples and described and figured it. He also cut sections and pointed out certain flask-shaped, unicellular glands as the source of the light.

Hans Molisch, while working at Trieste, with Cori, also saw the light in some of the species of this genus. Still other zoölogists have mentioned seeing this light to the writer, and have agreed that it is a weak greenish-white in color.

Dr. William Crozier, of the Bermuda Biological Station, has recently been studying the luminosity of these forms and has very kindly assisted the writer by sending him descriptions, figures, and preserved material. The form in which Doctor Crozier has seen the light to best advantage is a small species, probably *Ptychodena bahamensis,* Spengel, and they were dug out of the sand and placed in an aquarium in the station, where they were crawling about on the sandy bottom. In the evening, when the room was dark, a sharp tap on the glass side of the aquarium was sufficient to start them to lighting.

FIG. 14.

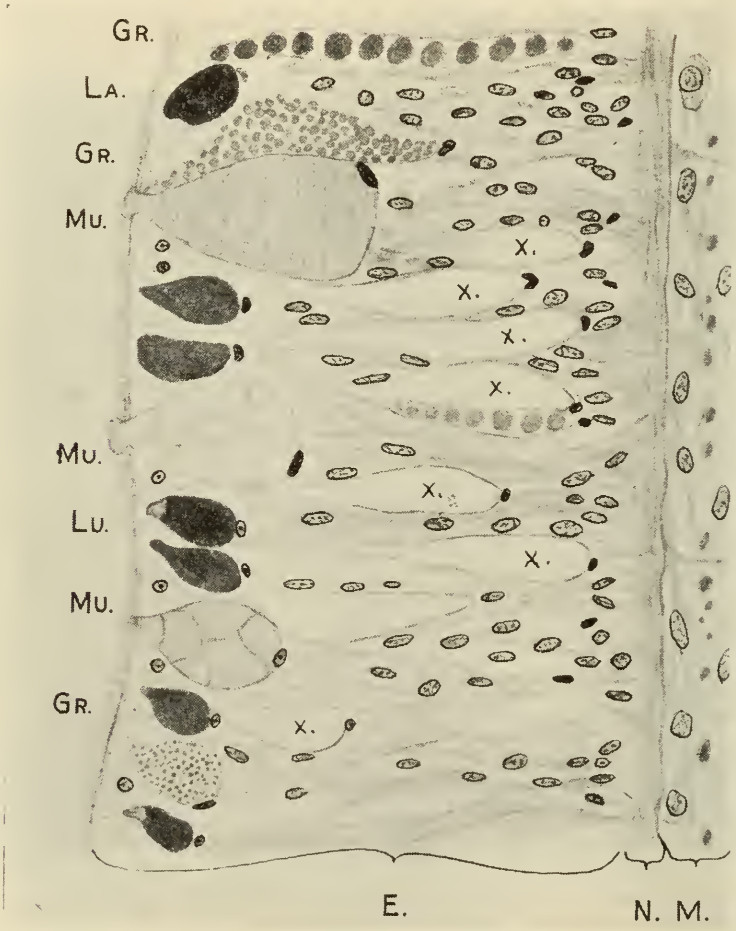


Appearance of three living specimens of *Ptychodena bahamensis* as they appeared in the aquarium at Bermuda on a dark night when stimulated by rapping on the glass. The light appears in encircling bands at various points on the body. Some slime, mixed with the luminous material, appears partly stripped off in one specimen. (Copied from a drawing by Dr. William Crozier, of the Bermuda Aquarium.)

The light appeared in one or more irregular bands around almost any portion of the body. Fig. 14 shows this clearly and is copied from a sketch made by Doctor Crozier while observing the living animals. The light is evidently an external discharge from epithelial glands, and the luciferine is mixed with some ordinary slime, so that it makes a viscous coating that can be stripped off from the skin on which it lies. In fact, it comes off without any aid, and in the figure, a portion of one of the bands may be seen partly loosened from the body. We have no data as to how often the light can be made to appear.

Sections of all parts of the body have been cut by the writer, and it was easy to see just how the lighting is accomplished. The body is everywhere covered by a deep, simple epithelium

FIG. 15.



View of a portion of a section of the body epithelium of *Ptychodena bahamensis* from just below the collar. *M*, muscle layer of integument; *N*, nerve-plexus in base of epithelium. Basement membrane is line dividing the two preceding zones. *E*, epithelium proper; *Lu*, luminous cells; *Gr*, granule cells with granules of different sizes in different cells; *Mu*, mucous cells; *X*, cells of unknown function whose contents have dissolved out in preparation. (Original drawing.)

whose elongate cells show an amount of differentiation comparable to that found in the higher worms and more highly organized Cœlenterates. Fig. 15 shows a view of a portion of this epithelium from the body at a point some distance below the collar. A definite and strong basement membrane (between *N* and *M*) is seen on which the bases of all cells rest. Interwoven on this membrane and forming a shallow layer (about one-twelfth the thickness of the entire epithelium) is a mass of fine fibrils which are in all probability mostly nerve-fibrils (*N*). Reaching outward from this layer are the cell-bodies of the epithelial cells, which for the most part are thin proximally and thicker distilly, so that a great many open spaces are seen in the proximal half or two-thirds of the layer. The greater part of the heavy secreting bodies of cytoplasm are seen in the distal portion of the epithelium. The outer ends of the cells form a straight, even line bearing short cilia that is broken here and there by the duct-like openings of the secreting cells. The cilia emerge from a striated border whose two boundaries form a double contour in which terminal bars are used to cement the cells together.

It is almost impossible to separate the cells or trace their individual outlines accurately, since so many of their bodies are very thin and irregularly shaped. The nuclei are very variable in size and appearance. We will classify and describe these cells with reference to the masses of secretion that we find, for the most part, in their distal ends.

Plainest of all and very numerous are the mucous cells (*Mu*). In iron hæmatoxylin stain their contents are quite transparent and do not stain. When mucin stains are used, as in the specimen drawn, the secretion stains darkly and shows the characteristic heavy reticulum of such cells in all animals when the mucigen granules are partly dissolved by water (see Fig. 15, *Mu*). The nuclei of these cells are large and rest well down toward the basal region.

The second type of cell (*Lu*) is taken by the writer to be the real light-cell. Its secretion forms a round, oval, or pear-shaped mass in the distal region, and the nucleus lies just proximal to and almost touching the secretion mass, which is often dented to partly enclose it. This secretion mass is pale yellow in life and also a slightly darker yellow in the sections stained with Delafield's hæmatoxylin or other mucous stains. When stained with iron hæmatoxylin and decolorized, as is usual in that method, the light-mass takes a deep black, while the mucous masses remain unstained. The distal end of the mass is pointed and near to its outlet. Often this distal end is light-staining and irregular. ' In most stains the mass appears to be homogeneous, but in deeply and clearly stained slides one can see that it is composed of fairly large granules closely pressed together or even only partly separated one from the other. These cells appear to be the luminous cells and their enclosed secretion the photogenin.

The third type of cell (*Gr*) contains as its secretion a mass of large granules. In staining reaction they resemble the last kind, but when fresh or decolorized they are transparent and almost invisible. Such cells are not as numerous as the former, but they are fairly well scattered over the whole body; also, the secretion mass is long and spindle-shaped, and extends down pretty well toward the proximal end of the cell. Some of them contain much smaller granules than others, and this may represent developmental stages. It seems possible that such cells may represent early stages of the mucous cells, as these stages have been described by Schneider in the case of the earthworm and other invertebrates. In Fig. 15, *Gr* represents this kind of structure.

One more cell remains to be accounted for. Its secretion mass is represented by a deep-lying vacuole, for the contents have all been dissolved out. We can only guess at the function. It may have been a fat that dissolved in the alcohol or xylol of clearing, or a watery fluid that was removed already at the time of clearing. Such cells are seen in Fig. 15, *X*. The nucleus is small and compact and is always lying against the proximal end of the spindle-shaped secretion vacuole. It is usually forced into a triangular shape by this contact. Like most of the other gland-cell nuclei, it is small, compact, and dark-staining. The nucleii of the undifferentiated epithelial cells are larger and more open in structure.

(*To be continued.*)

Dangers of Paper Fractional Currency. ANON. (*Revue Scientifique,* vol. 55, No. 4, February 3–10, 1917.)—Paper money of the small denominations of 50 centimes, one franc, and two francs, issued in the French provinces in consequence of a shortage of coin, have been found to be a very convenient medium of exchange, but unfortunately they become rapidly soiled and coated with germ-bearing matter. Analyses made by the municipal laboratory of Rouen show that this fractional currency, carrying but one per cent. of fatty matter when new (printing ink), in the course of many handlings rapidly accumulates fatty material to the amount of ten per cent. The danger of infection from this heavy coating of germ-bearing material is aggravated by the temptation to moisten the fingers with saliva in handling these notes.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

DURABILITY OF CEMENT DRAIN TILE AND CONCRETE IN ALKALI SOILS.[1]

BY

R. J. WIG, Engineer Physicist;
G. M. WILLIAMS, Assistant Engineer Physicist;
A. N. FINN, Associate Chemist,
Bureau of Standards

IN COÖPERATION WITH

S. H. McCRORY, Chief of Drainage Investigations,
Department of Agriculture

E. C. BEBB, Engineer,
U. S. Reclamation Service

L. R. FERGUSON, Engineer,
Portland Cement Association

[ABSTRACT.]

THE use of concrete, particularly for drainage structures, in soils containing quantities of alkalies found in the arid regions of the United States has been restricted because of lack of confidence on the part of some engineers as to its durability.

Several millions of dollars are being spent annually in the construction of engineering works in these regions, and appreciable savings could be had if concrete could be used without restriction. There are many localities in these regions in which concrete construction has proved durable and satisfactory, but in others disintegration has occurred, resulting in a prejudice against its further use. Concrete is often the most economical available structural material, and therefore a comprehensive investigation of its durability is of much importance to these localities.

This investigation is conducted in coöperation with the U. S. Reclamation Service, Drainage Division of the Department of Agriculture, and the Portland Cement Association.

It comprises the manufacture of 9000 cement drain tile of 20 different varieties and many concrete blocks, their shipment to

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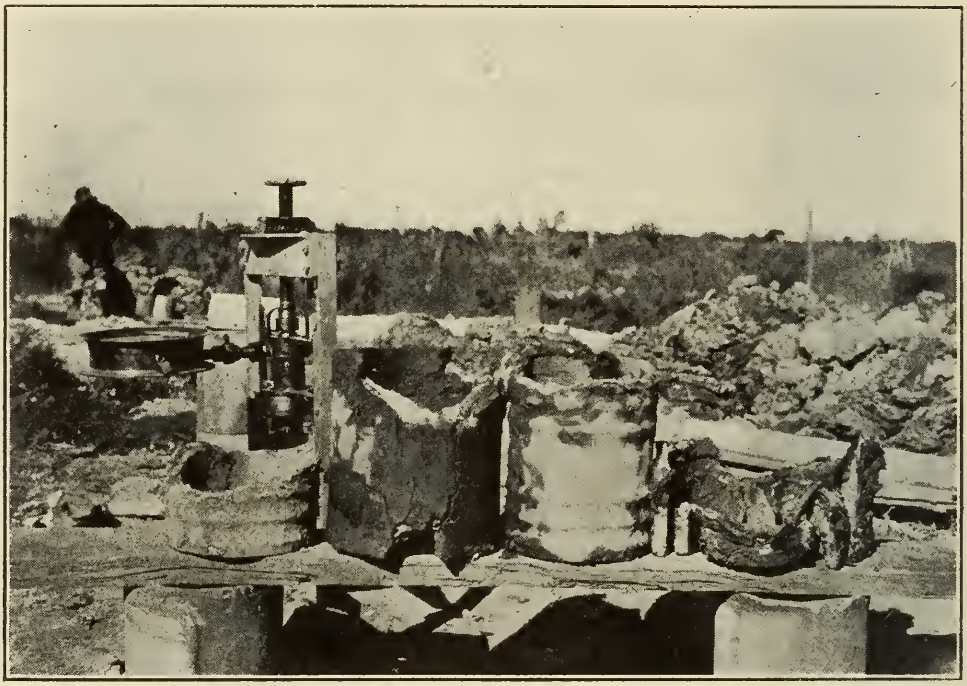
* Communicated by the Director.

[1] Technologic Paper No. 95.

projects in Colorado, Wyoming, Montana, Utah, Washington, South Dakota, Nevada, Arizona, and New Mexico, and to fresh-water projects in Minnesota and Missouri, and their installation in operating drains and seeped areas in districts where the alkali is greatly concentrated and in most cases where concrete failures were reported to have occurred.

Included in these varieties of tile were mixtures ranging from one part cement to one and one-half parts sand to one cement to four parts sand, both machine and hand-made, and cured in steam and by sprinkling with water. Practically all types and mixtures, commonly used in the humid region are represented, as well as others of greater wall thickness and wetter consistencies than can be made by most commercial tile machines. No special compounds or treatments have been used up to this time, except that one series each of tile were dipped in cement grout, another in hot tar, while ferrous sulphate was added to the mixing water of a third.

FIG. 1



Cement tile removed from drain near Grand Junction, Col., after three years' exposure to strongly alkaline drainage water. From left to right, Nos. 1, 3, and 4 are machine-made tile, plastic consistency, proportions 1 part cement to 4 parts sand. No. 2 is hand-moulded, plastic consistency, proportion 1 part cement to 2½ parts sand.

Concrete blocks or short columns were moulded at Denver, using the proportions 1 : 1.5 : 3 and 1 : 2.5 : 5, and a complete set of blocks were sent to eight projects of the Reclamation Service for installation in the most highly alkaline waters available on each. In addition, similar blocks were moulded on each project, using local materials, which were installed with the Denver blocks.

Crushing tests of the cement drain tile have been made yearly for the past three years, using a portable tile testing machine which can be set up at the site of the drain. The concrete blocks are inspected yearly, and signs of disintegration are carefully noted. Where disintegration has occurred, additional blocks have been moulded after special treatment of the aggregates.

Samples of alkalies, soils, and drainage waters have been collected and analyzed at intervals.

While complete conclusions as to the durability of cement drain tile and concrete in alkali soils similar to those included in this investigation cannot yet be drawn, the results of tests and observations to date may be summed up as follows:

1. CONCRETE.

Concrete which is to be placed in alkali soils should be made of selected and tested materials so proportioned as to produce a dense concrete. As small an amount of mixing water should be used as will allow the mass to be properly placed. Unless these precautions are taken the resistance of the concrete to alkali action will be reduced.

2. DRAIN TILE.

The following conclusions may be drawn for the use of cement drain tile exposed to soils or waters containing alkali salts in quantities of 0.1 per cent. or more:

1. The use of cement tile in soils containing alkali salts in large quantities is experimental.

2. Porous tile due to the use of lean mixtures or relatively dry consistencies are subject to disintegration.

3. Some dense tile are under certain conditions subject to surface disintegration.

4. Disintegration is manifested by physical disruption caused by the expansion resulting from the crystallization of salts in the

pores and by softening, resulting from chemical action of the solutions with the constituents of the cement.

5. While results obtained will not permit of a definite statement as to the relative effect of the various constituents of the salts, indications are that the greater the quantity of sulphate and magnesium present and the greater the total concentration of salts, the greater will be the disintegrating effect.

6. Tile made by the process commonly used, which allows the removal of forms immediately after casting are subjects to disintegration where exposed to soils or waters containing one-tenth per cent. or more alkali salts similar in composition to those encountered in this investigation.

7. The hand-tamped tile of plastic consistency as made in this investigation are not equal in quality to machine-made tile of the same mixture, and they do not resist alkali action as well.

8. Steam-cured tile show no greater resistance to alkali action than tile which are cured by systematic sprinkling with water.

9. Tile made of sand-cement have less resistance to alkali action than tile made of Portland cement of the same proportions.

10. The tar coating as used is not effective in preventing the absorption of alkali salts from the soil.

11. The cement grout coating is not effective in preventing the absorption of alkali salts from the soil.

12. No advantage is found in introducing ferrous sulphate into the cement mixture.

If cement drain tile are to be used in alkali soils or water containing 0.1 per cent. or more of salts, similar in composition to those encountered in this investigation, they should be made of good quality aggregate in proportions of not less than one part Portland cement to three parts aggregate. The consistency should preferably be quaking, which has proved the most resistant of all mixtures used. This is wetter than that generally used in commercial tile plants and will probably require the retention of the tile in the moulds for several hours, unless some means are found to hasten the hardening of the cement.

This paper is now in press and copies will be furnished when issued to those who apply to the Bureau of Standards, Washington, D. C.

GLASSES FOR PROTECTING THE EYES FROM INJURIOUS RADIATIONS.*

By W. W. Coblentz and W. B. Emerson.

The object of the present paper is to give the general characteristics of certain newly-developed glasses sometimes used for protecting the eye from radiant energy, especially the infra-red or so-called heat rays. Because of the difficulty in reproducing the same color in different melts, no attempt is made to give specific data on the transmission for a given thickness of glass. In order to obtain exact data it is necessary to examine samples from each melt.

These data are representative of an extensive group of glasses available for protecting the eye from (1) the ultra-violet, (2) the visible, and (3) the infra-red rays.

For protecting the eye from ultra-violet light, black, amber, green, greenish-yellow, and red glasses are efficient. Spectacles made of white glass afford some protection from the extreme ultra-violet rays which come from mercury-in-quartz lamps and from electric arcs between iron, copper, or carbon. The vapors from these arcs emit but little infra-red radiation in comparison with the amount emitted in the visible and in the ultra-violet.

For shielding the eye from infra-red rays, deep black, yellowish-green, sage-green, gold-plated, and bluish-green glasses are efficient. For working near furnaces of molten iron or glass if considerable light is needed, a light bluish-green or sage-green glass is efficient in obstructing the infra-red rays. For working molten quartz, operating oxy-acetylene or electric welding apparatus, or other intense sources of light, it is important to wear the darkest glasses one can use, whether black, green (including gold-plated glasses), or yellowish-green, in order to obstruct not only the infra-red but also the visible and the ultra-violet rays.

Data are given showing that of the infra-red rays emitted by a furnace heated to 1000 to 1100° C. (1) about 99 per cent. are obstructed by gold-plated glasses, (2) about 95 per cent. by sage-green or bluish-green glasses, (3) about 80 per cent. by very deep black glasses, and (4) about 60 per cent. by greenish-yellow glasses.

At higher temperatures these data would be somewhat different, but not sufficiently so to modify the rough estimates dealt with in this paper.

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* Technologic Paper No. 93.

AN "AVERAGE EYE" FOR HETEROCHROMATIC PHOTOMETRY, AND A COMPARISON OF A FLICKER AND AN EQUALITY-OF-BRIGHTNESS PHOTOMETER.*

By E. C. Crittenden and F. K. Richtmyer.

[ABSTRACT.]

THE comparison of lights of different colors is supposed to be based on an " average normal eye." This paper records an attempt to approximate the results of such an eye with typical color differences by using a large number of observers. In particular, results obtained by a flicker photometer and by an equality-of-brightness photometer, with different degrees of color difference, are compared. In terms of the Ives-Kingsbury test solutions, for which the proposed normal ratio of transmissions (with a 4 wpc. carbon lamp) is 1.00, the average of 114 observers gives a ratio of 0.99. By using these test solutions results obtained on the flicker photometer by a small number of observers can be corrected so as give normal values with a high degree of accuracy. On the average, equality-of-brightness measurements also vary in proportion to the test ratio, but erratic variations often overshadow these systematic differences. For sources having relatively high intensity in the blue, flicker values tend to fall below those obtained on the usual standard photometers, but the difference is comparable in magnitude with the uncertainty of the latter values.

TEMPERATURE MEASUREMENTS IN BESSEMER AND OPEN-HEARTH PRACTICE.†

By George K. Burgess.

[ABSTRACT.]

THE problem of temperature measurement and pyrometric control of furnace casting and ingot teeming temperatures is shown, by a series of observations taken in several steel plants, to present no serious difficulties or uncertainties.

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* Scientific Paper No. 299.

† Technologic Paper No. 91.

For this purpose the most satisfactory type of instrument is one of the optical pyrometers using monochromatic light and permitting observation from a distance of streams of metal.

It is shown that the necessary corrections to the observed optical pyrometer readings for emissivity of metal and oxides to give true temperatures are sufficiently well known, but there may be uncertainty in the case of liquid slags.

For streams of liquid iron or steel the most probable value of emissivity to take, with a pyrometer using red light of wave-length $\lambda = 0.65\ \mu$, is $e = 0.40$, corresponding to a correction of 139° for an observed temperature of 1500° C. The value of e for liquid slags is usually about 0.65, but varies with composition of the slag. A table of emissivity corrections is included in the text.

Determination of the temperature of the charge of Bessemer converters is not deemed practicable by pyrometric methods.

The operation of the open-hearth furnace can be gauged by the pyrometer, it being possible to control readily the temperature of the roof and of the bath of metal and slag by observations taken through ports; and the temperature of the metal may be had at any instant, with a fair degree of exactness, by observation with the optical pyrometer of metal removed in a spoon.

The temperatures of the roof of an open-hearth furnace are shown to bear no necessary relation to that of the metal bath, which it is again shown may have zones of considerable differences in temperature, depending upon the operation of the furnace.

The temperature of the roof of an open-hearth furnace, dependent upon the firing practice, may vary very rapidly and within wide limits, 1550° to 1750° C. The temperature of the open-hearth bath is usually kept between 1600° and 1670° C.

There appears to be a remarkable degree of uniformity in casting temperature actually acquired by the melters in practice. Thus for nineteen consecutive Bessemer heats the teeming temperatures of the ingots were all between 1500° C. and 1555° C., and a similar degree of concordance, although at slightly higher temperatures, was found in the open-hearth practice of several mills.

It is believed that a continuous, systematic following of the temperature, by the methods above outlined, for the various furnace and casting practices, on the part of steel and iron mills, would show the possibility of improvements and greater certainty of production in quality of product; also, changes and the effects of variation in ingot or furnace practice could undoubtedly be carried out with greater certainty than at present appears to be the case.

Burning Coal Beds Form Natural Brick. Anon. (*U. S. Geological Survey Press Bulletin. No. 314*, March, 1917.)—Many coal beds in the great coal fields of the western states have at some time taken fire and burned along their outcrops, baking and reddening the overlying strata so that they have become a kind of natural brick or terra-cotta. The fires were in places hot enough to fuse and recrystallize the overlying shale and sandstone so as to form natural slag. At some places this slag resembles true igneous rock; at others it consists largely of rare minerals. Thoroughly fused slag seems to occur chiefly in crevices or chimneys through which the hot gases generated in the burning escaped through the overlying strata to the surface. The chimney-shaped masses of slag are harder than the surrounding baked rock and, after that has weathered away, form the curious pinnacles that surmount many clinker bluffs or buttes in the west.

Some of the coal beds, especially those exposed on the higher hills, were perhaps ignited by lightning; others, according to well-authenticated reports, were ignited by prairie fires or camp fires; but as burning on the outcrop has been so common as to affect most of the coal beds in an area of more than 200,000 square miles, much of it has probably been due to spontaneous combustion.

Coal beds are now burning at or near the surface at many places in the west, where the burning of the bed is disclosed by the smoke and fumes that rise from it and by the heat at the surface of the earth near the outcrop or above the bed—heat so intense that it kills all vegetation. As the coal burns out the overlying rock or earth generally caves in so as to form large fissures in the ground. As the burning works back from the outcrop, the heat acts on the overlying rocks, but finally combustion is smothered for the lack of oxygen. It is difficult to say how far back from the outcrop the burning may extend. Field studies made by the United States Geological Survey, Department of the Interior, indicate that a bed lying beneath 20 feet or less of cover may burn out completely under large areas, and even where the cover is several hundred feet thick the burning may extend 500 feet back from the outcrop.

A brief account by G. S. Rogers of the burning of coal beds in place, with a discussion of the causes and a petrologic and chemical description of some of the baked and fused rock formed, has been published by the United States Geological Survey as Professional Paper 108—A. A copy of this report may be obtained free on application to the Director of the Survey.

NOTES FROM NELA RESEARCH LABORATORY.*

THE EQUALITY-POINT IN SPECTRAL ENERGY AND LUMINOSITY-DISTRIBUTION CURVES OF ILLUMINANTS.

By M. Luckiesh.

In plotting relative spectral energy-distribution curves of illuminants it is advantageous to choose a wave-length of equality. It is a common procedure to multiply these relative spectral energy-values by the spectral visibility-values to obtain the spectral luminosity-distributions. The latter, when integrated, of course, cannot be directly compared with each other on either the basis of equal luminous efficiency or luminous intensity. It has been of interest to compute the relative luminous intensities in the foregoing manner, using the relative energy-values of the spectral distribution curves made equal at different wave-lengths between 0.57 μ and 0.59 μ and including in these computations noon sunlight and blue skylight. The results are shown in the accompanying illustration. The results are subject to change with any change in the visibility data. For the present purpose Nutting's visibility data (*Trans. I. E. S.*, 1914, **9**, p. 633) have been used.

It is seen that the luminosities are more nearly equal for those common illuminants of extremely different spectral energy-distribution when the equality-point is in the neighborhood of 0.565 μ. This is much nearer the wave-length of maximum visibility than the customary equality-point, 0.59 μ. In the latter case it is seen that there is a wide variation between the resultant relative integral luminosities of blue skylight and the group of artificial illuminants. Incidentally Fig. 1 illustrates that Crova determined fairly closely the wave-length at which photometric measurements would yield results in fair agreement with those made with the integral lights from artificial light-sources in use at that time. His proposed screen transmitted maximally at 0.582 μ. It appears that for most of the common artificial illuminants in use to-day photometric measurements made at a wave-length near 0.575 μ would yield results closely proportional to the integral luminosity-values. For the general case which includes illuminants such as skylight and sunlight, and thus representing the extremes, a wave-length near 0.565 μ appears to be the most desirable point for plotting energy and luminosity-values equal. In the latter case the extreme error would not be more than 10 per cent. in comparing the two illuminants most widely different in spectral character. Even this error might not be too great for some classes of photometry involving the comparison of daylight intensity with an artificial standard of luminous intensity. The advantage of such a screen in eliminating or reducing color-difference in investigating natural lighting is obvious. At any rate, it appears that it would be advisable to adopt 0.565μ as the equality-point in plotting spectrophotometric data and to abandon the use of 0.59 μ. It is interesting to note the results obtained for the radiation from the gas mantle, which departs widely in spectral distribution from that of the black body and many of the common illuminants.

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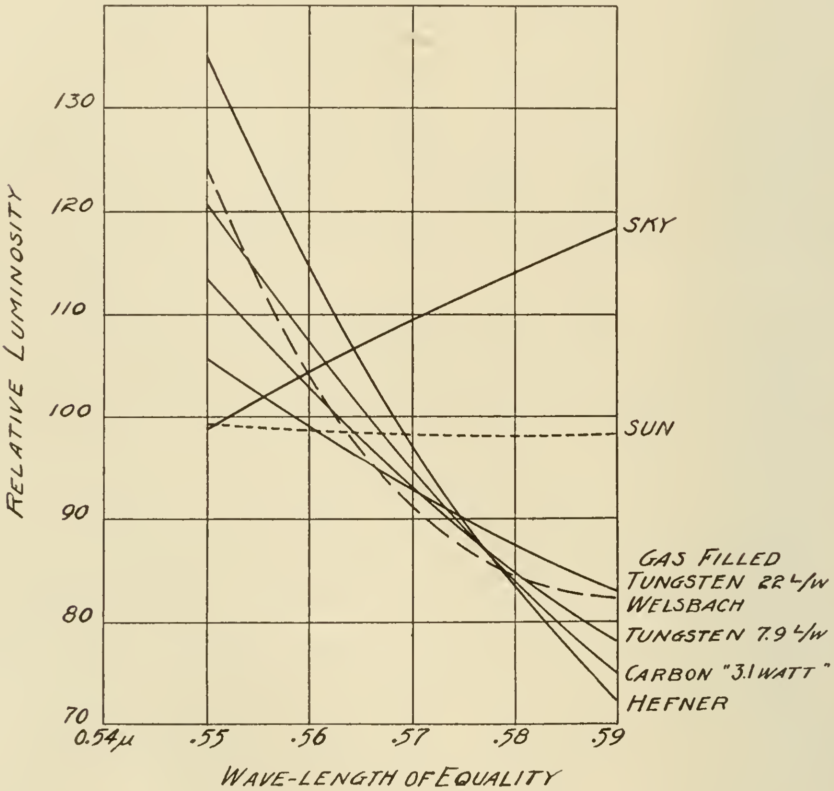
* Communicated by the Director.

FIG. 1.



NOTES FROM THE RESEARCH LABORATORY, EASTMAN KODAK COMPANY.*

THE PHOTOGRAPHIC PRODUCTION OF A LITHOGRAPHIC KEY ON ZINC AND ALUMINUM.[1]

By J. I. Crabtree.

[ABSTRACT.]

In order to facilitate the work of the lithographic artist when drawing in crayon on zinc or aluminum, it is possible to first prepare a photographic image on the metal plate to serve as a key, which may then be worked upon in the usual way. This key may be obtained by an application of the blue-print process to metal, though in order to prevent the final image from washing off the plate it is necessary to pay attention to the following details:

A suitable sheet of grained zinc is first coated with a 1 per cent. solution of citric acid and dried immediately. The following sensitive coating is then applied with a brush and likewise dried immediately:

(A)	Ferric ammonium citrate (Bown scales)	30 g.	1 oz. 25 gr.
	Water to	150 c.c.	5 oz.
(B)	Potassium ferricyanide	30 g.	1 oz. 25 gr.
	Water to	150 c.c.	5 oz.

For use: 3 parts A; 1 part B.

After exposing under a negative until the shadows are slightly bronzed, the plate should be washed in water, when a blue image results, though a much stronger image may be obtained if the plate is developed in a solution consisting of equal parts of a 1 per cent. solution of potassium ferricyanide and a 1 per cent. solution of citric acid. The high-lights of the zinc may be considerably whitened and the contrast thereby increased by treating the zinc with a weak solution of nitric acid and alum.

A key may be prepared on aluminum in a manner very similar to the method for obtaining the same on zinc. A suitably grained sheet of aluminum is first coated with a 1 per cent. solution of oxalic acid and dried quickly before a fan. The aluminum is then coated with the ferric ammonium citrate-potassium ferricyanide mixture, as in the case of zinc, and rapidly dried. After exposure, the plate should be developed in plain water, though if a solution consisting of equal parts of 1 per cent. oxalic acid and 1 per cent. potassium ferricyanide is used a bluer and slightly more intense image is obtained.

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* Communicated by the Director.

[1] Communication No. 48 from the Research Laboratory of the Eastman Kodak Company, published in *The National Lithographer* and *British Journal of Photography.*

A COMPENSATING FILTER IN SPECTROSCOPY.*

By M. B. Hodgson and R. B. Wilsey.

[ABSTRACT.]

It would be desirable in many spectral investigations to have a photographic emulsion which would yield, in the same exposure, equal densities in the developed negative over a wide spectral region when using a light source having a continuous spectrum. Needless to state, while present-day panchromatic dry plates show sensitiveness throughout the whole visible spectrum, and while the modern high-efficiency illuminant is constant in radiant output and more uniform in spectral distribution than heretofore, such an ideal condition does not exist; the sensitiveness of the plate is not a constant value for all wave-lengths, nor is the energy-distribution of the illuminant even approximately uniform.

To overcome these inherent defects, in obtaining quantitative or reliable qualitative measurements of absorption bands, various expedients are employed.

Luckiesh has described a method which he has used with success in obtaining uniform photographic intensity throughout the spectrum, using a light source yielding a continuous spectrum. Morris-Airey suggested this method in 1913.

The spectrum of the light source used is first photographed in the usual manner upon the particular brand of panchromatic plates selected, exposing through the glass, this last in order that re-focusing of the spectrum may be dispensed with in subsequent exposures. This initial negative is then developed, fixed, dried, and further exposures made, using it as a filter in contact with the emulsion of the print plate, its position coinciding with its original position, thus bringing the screen and print-plate emulsion in approximately the same focal plane. The theory is that those portions of the spectrum which are most actinic will be restrained, in proper ratio, by the densities they have impressed upon the initial plate.

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* Communication No. 42 of the Research Laboratory of the Eastman Kodak Company, published in the *Journal of the Optical Society*.

The authors have further investigated this process and determined the photographic constants involved.

Let $I\lambda$ be the intensity of radiation of the wave-length λ, $T\lambda$ the transmission of the compensating filter at that point in the spectrum, and $S\lambda$ the speed or sensitiveness of the photographic emulsion for that particular wave-length. Then

$$I_\lambda \, T_\lambda \, S_\lambda = K \tag{1}$$

where K is a constant, is the condition necessary for obtaining equal densities for all wave-lengths upon a photographic plate through the compensating filter.

Density being defined in terms of transmission as follows:

$$\text{Opacity, } O_\lambda = \frac{1}{T_\lambda}$$

$$\text{Density, } D_\lambda = \log O_\lambda = -\log T_\lambda$$

The condition (equation 1) to be fulfilled by the compensating filter may be expressed

$$D_\lambda = \log I_\lambda + \log S_\lambda - \log K \tag{2}$$

$D\lambda$ refers to the compensating filter and $S\lambda$ to the emulsion on which further "prints" are to be made; the value of K is arbitrary, depending on the density produced in the print plate. It is only required that K be constant for all wave-lengths.

Gun Versus Armor. J. B. WALKER. (*Scientific American,* vol. cxvi, No. 14, p. 346, April 7, 1917.)—The excessive ranges at which naval engagements have been fought have been among the surprises of the present war. For several years prior to 1914 target practice was carried on in our own navy at ranges of

9000 to 10,000 yards, and, so far as we know, 10,000 yards was accepted by the foreign navies as the maximum at which it was necessary to train the gun crews for the actual ordeal of battle. Early in the war, however, it was realized that fighting was going to be done at the maximum ranges at which the ship having the speed-gauge could land effectively on the enemy, and engagements have taken place at 12,000, 15,000, and 20,000 yards. With the continually increasing calibres of naval guns, and pieces as large as 18 and 20 inches calibre contemplated, it is quite conceivable that future engagements will be fought at ranges varying between 20,000 and 25,000 yards according to conditions of visibility.

The armor plan of most existing battleships is drawn up to meet conditions of attack at ranges of 8000 to 10,000 yards. The vitals of the ships are protected by a heavy water-line belt associated with a protective deck about three inches in thickness. In some of the later ships there are two protective decks, one in the usual position just above the water-line and the other at the gun deck at the level of the top of the belt. The ammunition hoists and the barbette and turret mechanism are protected by thick vertical armor, and the turret by a heavy sloping port-plate associated with lighter armor on the side walls and at the rear, and light armor 3 to 5 inches in thickness on the roof. The present method of distributing the armor was designed to meet the conditions of 10,000-yard ranges where the angle of impact of the projectile is about 6 degrees with the horizontal. With an impact angle of 22 degrees resulting from ranges greater than 20,000 yards, it is a question whether our present methods of armor distribution should not be altered to meet the new conditions.

Taking it for granted that the vitals of the ship should have the first call upon the armor, it would seem that efforts should be directed to bursting the high-explosive shells as far above the protective deck as possible, on the probability that where an unexploded shell might go through, its fragments would not. It becomes a pertinent consideration, then, whether it is not better to distribute the heavy belt in the form of lighter armor extending over the whole side of the ship, retaining the 2-inch armor of the protective deck, and armor the upper deck in preference to the gun deck. The complete armoring of the above-water portion of the ship would go far to insure the bursting of the shells as soon as they entered. The probability is that the shock of penetrating this outer armor would cause the shell to burst above the main deck, and in any case there would be the additional shock of passing through the main and gun decks to cause fragmentation before the protective deck was reached.

THE FRANKLIN INSTITUTE

(*Proceedings of the Stated Meeting held Wednesday, April 18, 1917.*)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 18, 1917.

PRESIDENT DR. WALTON CLARK *in the Chair.*

Additions to membership since last report, 13.

Mr. William C. Wetherill, chairman of the Committee on Science and the Arts, reported the condition of the work of the committee.

Charles Baskerville, Esq., Ph.D., Director of Chemical Laboratories, College of the City of New York, presented a communication on the "Hydrogenation of Oils." The various saturated, unsaturated, and hydroxy acids, which occur in animal and vegetable fats and oils, were described by means of charts. The mixed glycerides of such fats and oils were discussed, together with the successive changes produced in their unsaturated radicals by hydrogenation. Attention was paid to the rôle of catalysis in hydrogenation, and to the factors which may favor or retard the reaction in its commercial application. Stress was laid on the economic importance of hydrogenated oils, and the relationship of such oils to the natural fats.

The subject was illustrated by experiments and lantern slides.

After a brief discussion the thanks of the meeting were extended to the speaker.

Adjourned.

R. B. OWENS,
Secretary.

THE FRANKLIN INSTITUTE SCHOOL OF MECHANIC ARTS.

ANNUAL REPORT OF THE DIRECTOR OF THE SCHOOL.

1916–1917.

COURSES OF INSTRUCTION.

The ninety-third year of The Franklin Institute School of Mechanic Arts closed April 13th, 1917. During the year instruction was given in Mechanical Drawing, Architectural Drawing and Design, Freehand Drawing and Water Color, Shop Arithmetic and Algebra, Plane Geometry and Trigonometry, Applied Mechanics and Machine Design, and Theoretical and Practical Naval Architecture.

The courses in Mechanics and Naval Architecture were extended and instruction was given three evenings a week instead of two as in the past.

REGISTRATION.

The total registration for the year was three hundred and seventy-two, an increase of 21 per cent. over that of last year. Large classes were enrolled in First Year Mathematics and in First Year Mechanical Drawing. A marked interest was shown in the course in Naval Architecture.

ATTENDANCE AND PROGRESS.

Because of the unprecedented activity in the industrial plants many of the students were unable to attend classes regularly. However, during the first term thirty-eight students had a perfect attendance record and forty-eight had a perfect attendance record during the second term. In the regular school work forty-one students made an average of 90 per cent. or over during the first term, and thirty-five an average of 90 per cent. or over during the second term.

The high grade of work done by the students in all classes and the large enrollment indicate that the school has completed one of the most satisfactory years in its history.

FACULTY.

In order to give more personal attention to each student the Committee on Instruction decided to limit the size of each class to approximately twenty-five. This plan made it necessary to increase the number of instructors, and the following gentlemen were appointed:

Dr. Ross W. Marriott, of Swarthmore College Faculty, Mathematics.

Mr. Wm. F. Turnbull, of the University of Pennsylvania Faculty, Mechanical Drawing.

Mr. Arthur J. Stretton, Baldwin Locomotive Works, Mechanical Drawing.

Mr. Joseph W. Thompson, New York Shipbuilding Company, Naval Architecture.

Mr. C. J. Walton, Engineering Department, Bell Telephone Company, Mathematics.

Mr. Howard S. Eitzel, Phillips Brooks School, Mathematics.

Mr. Joseph L. Mounce, of the University of Pennsylvania Faculty, was appointed to continue the work of Mr. Frank H. Lobb, in Mechanical Drawing, who resigned on November 9, 1916.

SCHOLARSHIPS.

Eighteen scholarships were available for students of the School; five of these were Bartol Scholarships in Drawing, derived from the B. H. Bartol Fund; thirteen scholarships were derived from the Isaac B. Thorn Fund, and were awarded to students in Mathematics, Mechanics and Naval Architecture.

PRIZES.

Valuable prizes were offered by the following gentlemen for meritorious work in the various departments:

Mr. Samuel M. Vauclain, Vice-President, The Baldwin Locomotive Works.

Mr. J. B. McCall, President, Philadelphia Electric Company.

Mr. Wilfred Lewis, President, Tabor Manufacturing Company.

Mr. J. T. Wickersham, Secretary and Treasurer, The New York Shipbuilding Company.

Mr. Robert W. Lesley, Past-President, Portland Cement Association and Member of the Board of Managers of The Franklin Institute.

The Alumni Association continued its special prizes to the graduates having the best records and to graduates having a perfect attendance for the year.

HONORS.

Certificates for the satisfactory completion of a course in one of the Departments of Drawing, Mathematics, Mechanics or Naval Architecture are this year awarded to forty-one students. Appended are the names of these graduates, also the names of those students to whom are awarded the scholarships and prizes indicated above, and the names of those students granted certificates of Honorable Mention for regularity of attendance and proficiency in class work.

The success of the year that has just closed may be attributed to the hearty coöperation of officials of the various manufacturing plants, to the earnest and the continued application of the students, and to the conscientious work done by the members of the Faculty.

Respectfully submitted,

SIMEON VAN T. JESTER,
Director.

April 20, 1917.

LIST OF GRADUATES, ETC., 1916–17.

CERTIFICATES.

CERTIFICATES ON THE SATISFACTORY COMPLETION OF FULL COURSES ARE AWARDED AS FOLLOWS:

MECHANICAL DRAWING.

Lloyd B. Avis.
W. C. Callingham
Dirk A. Dedel
Ludwig Frank
Oscar Goertz
John Hysore
George Jahke
Jay C. Lafferty, Jr.
Robert Morris
John MacConnell
H. J. Schmid

ARCHITECTURAL DRAWING.

Leon Chatelain, Jr.
N. A. Hansen
Ferdinand A. Noll
Everett B. Powers
Albert Witt

FREEHAND DRAWING AND WATER COLOR.

Christian P. Kopp

MATHEMATICS.

Branson Barnes
John R. Blowe
Joseph A. Chamberlain
Edward S. DeHart
Harry Haering
Clarence H. Jaggers
Harry Kretzschmar
E. Branson Parker
Aden W. Powell
Robert J. Roesch
Frank Rorer, Jr.
W. C. Schmoll
Carl W. Slemmer
Rudolph K. Wood

MECHANICS.

Benjamin A. Beavan
John F. Casey
George D. Collar, Jr.
Raymond J. Davis
Jacob H. Finkelstein
Joseph G. Floody
Abraham Perlman
W. Frank Titus

NAVAL ARCHITECTURE.

Thomas I. Cooper
Carl Schultz

BARTOL SCHOLARSHIPS.

Department of Drawing.

George W. Hardman
  Architectural
Russell Morehouse
  Mechanical
Jessie J. Moyer
  Architectural
Wilson D. Scott
  Mechanical
D. P. Smith
  Mechanical

THORN SCHOLARSHIPS.

Department of Mathematics.

Frank Baker
Joseph Chamberlain
Edward S. DeHart
Randall Ellis
Thomas C. Gatley
Andrew Hetherington
Robert Hetherington
William Kuenstle
John Schaad
Rudolph K. Wood

Department of Naval Architecture.

Roscoe Bateman
Theodore G. Grier
John L. Starr

MR. S. M. VAUCLAIN'S PRIZE.

MECHANICS.

John F. Casey

MR. WILFRED LEWIS' PRIZE.

MECHANICS.

Joseph G. Floody

MR. J. B. McCALL'S PRIZE.

MATHEMATICS.

Aden W. Powell

MR. ROBERT W. LESLEY'S PRIZE.

DRAWING.

John MacConnell

NEW YORK SHIPBUILDING COMPANY'S PRIZE.

NAVAL ARCHITECTURE.

Thomas I. Cooper

ALUMNI ASSOCIATION OF THE FRANKLIN INSTITUTE'S PRIZES.

Aden W. Powell
  Mathematics
John F. Casey
  Mechanics
Carl Schultz
  Naval Architecture
Ferdinand A. Noll
  Architectural Drawing
John MacConnell
  Mechanical Drawing

COMMITTEE ON SCIENCE AND THE ARTS.

(*Abstract of Proceedings of the Stated Meeting held Wednesday, April 4, 1917.*)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 4, 1917.

MR. WM. CHATTIN WETHERILL *in the Chair.*

The following reports were presented for first reading:

No. 2683.—Yeoman's Method of Machine Construction.

No. 2687.—Portable Brinell Meter.

The following report was presented for final action:

No. 2688.—Becker's Chainomatic Balance.

Edward Longstreth Medal of Merit to Christopher A. Becker, of New York City, N. Y.

On the recommendation of the Sub-committee on Literature, the following awards were made for papers in the JOURNAL, 1916:

No. 2696.—The Howard N. Potts Medal to Prof. Ulric Dahlgren, of Princeton, N. J., for his paper, entitled "The Production of Light by Animals," described by the Sub-committee as forming an original and comprehensive treatise of an extremely interesting and important subject.

No. 2697.—The Edward Longstreth Medal of Merit to Mr. George A. Rankin, of Washington, D. C., for his paper, entitled "Portland Cement," described by the Sub-committee as a highly important contribution to the theory of cement chemistry.

No. 2698.—The Edward Longstreth Medal of Merit to Prof. A. E. Kennelly, of Cambridge, Mass., for his paper, entitled "Experimental Researches on the Skin Effect in Steel Rails," described by the Sub-committee as containing new and valuable experimental data, heretofore unavailable to the designers of track return systems.

No. 2699.—The Edward Longstreth Medal of Merit to Mr. John D. Ball, of Schenectady, N. Y., for his paper, entitled "Investigation of Magnetic Laws for Steel and Other Material," described by the Sub-committee as containing new and valuable information relating to the magnetic properties of materials used in the magnetic circuits of electrical machinery.

No. 2700.—The Edward Longstreth Medal of Merit to Prof. Dayton C. Miller, of Cleveland, Ohio, for his papers, entitled "A 32-Element Harmonic Synthesizer," and the "Henrici Harmonic Analyzer and Devices for Extending and Facilitating its Use," described by the Sub-committee as a comprehensive and lucid discussion of harmonic synthesis and analysis, together with descriptions of perfected apparatus for synthesizing and analyzing functions of one variable expressible by Fourier's equation.

R. B. OWENS,
Secretary.

SECTIONS.

Section of Physics and Chemistry.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, March 29, 1917, at 8 o'clock, with Dr. Gellert Alleman in the chair. The meeting was held in conjunction with the Philadelphia Section of the American Chemical Society. The minutes of the previous meeting were read and approved.

H. S. Mork, B.S., of Arthur D. Little, Incorporated, Boston, Mass., delivered an address on "The Chemistry of Cellulose and its Important Industrial Applications." The chemical composition of cellulose was discussed and its reactions were described, especially those reactions which form the basis of the manufacture of viscose, cellulose nitrates, cellulose acetates, cellulose ethers, and artificial silk. The properties of these products and their applications in the arts were outlined. The lecture was illustrated with specimens. After a discussion of the paper, a vote of thanks was extended to Mr. Mork and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

Section of Physics and Chemistry.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, April 5, 1917, at 8 o'clock, with Dr. Gellert Alleman in the chair. The minutes of the previous meeting were approved as read.

Wilder D. Bancroft, Ph.D., Professor of Physical Chemistry in Cornell University, presented a communication on "Contact Catalysis," in which the theory of that phenomenon and its applications in inorganic, organic, biological, and industrial chemistry were discussed at length.

On motion of Mr. Louis E. Levy, a vote of thanks was extended to Dr. Bancroft, and he was requested to submit his paper for publication in the JOURNAL OF THE INSTITUTE. The paper was discussed and the meeting then adjourned.

JOSEPH S. HEPBURN,
Secretary.

Section of Physics and Chemistry.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, April 12, at 8 o'clock, with Dr. George A. Hoadley in the chair. The minutes of the previous meeting were approved as read.

William Albert Noyes, Ph.D., LL.D., Director of the Chemical Laboratory of the University of Illinois, and editor of the *Journal of the American Chemical Society,* delivered an address on "The Electron Theory." The developments in the knowledge of matter and energy, and of their relation to each other, were traced, from the time of the discovery of oxygen to the present. An account was given of the discovery of electrons or atoms of negative electricity. The nature of the attractions between atoms, which cause them to unite to form compounds, was discussed. The lecture was illustrated with lantern slides and experiments.

The paper was discussed by Doctors Brush, Morley, Hoadley, Cope, Kershner, and others. A vote of thanks was extended to Doctor Noyes, and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

MEMBERSHIP NOTES.

ELECTION TO MEMBERSHIP.

(*Stated Meeting Board of Managers, April 11, 1917.*)

RESIDENT.

DR. BERTHA MAY CLARK, Head of Science Department, William Penn High School, and for mail, 1904 Green Street, Philadelphia, Pa.

MR. WAYNE S. EVANS, S. W. Evans & Son, 4623 Paul Street, Frankford, Philadelphia, Pa.

MR. JONATHAN JONES, Civil Engineer, 530 City Hall, Philadelphia, Pa.

MR. HENRY W. LEBOUTILLIER, Chemist, Wayne, Pa.

NON-RESIDENT.

MR. G. W. CREIGHTON, General Superintendent, Eastern Pennsylvania Division, Pennsylvania Railroad Company, Altoona, Pa.

MR. E. M. FITZ, Electrical Engineer, Motive Power Department, Pennsylvania Lines West of Pittsburgh, Columbus, Ohio.

DR. MILTON W. FRANKLIN, Research Engineer, E. F. Houghton & Company, 240 West Somerset Street, Philadelphia, Pa.

MR. R. E. GLOVER, Chemist, Experimental Station, E. I. du Pont de Nemours Company, and for mail, 1411 Jackson Street, Wilmington, Del.

MR. HERMAN LIVINGSTON, Hydro-Carbon Engineer, Ætna Explosives and Ætna Chemical Companies, P. O. Box 543, Carnegie, Pa.

MR. PERCY MCGEORGE, Prætorian Building, Dallas, Texas.

MR. J. J. RHOADS, Sperintendent, Schuylkill Division, Pennsylvania Railroad Company, and for mail, 957 Centre Avenue, Reading, Pa.

MR. N. W. SMITH, Superintendent, Middle Division, Pennsylvania Railroad Company, Altoona, Pa.

MR. ETHAN VIALL, Western Editor, *American Machinist,* 3556 Montieth Avenue, Hyde Park, Cincinnati, Ohio.

CHANGES OF ADDRESS.

MR. W. H. CRAGO, Room 3623, 120 Broadway, New York City, N. Y.

PROF. W. S. FRANKLIN, Washington, Conn.

MR. J. ROGERS HOLCOMB, Wilmington Steel Company, Wilmington, Del.

MR. MORRIS KNOWLES, 1200 B. F. Jones Law Building, Fourth Avenue and Ross Street, Pittsburgh, Pa.

MR. MARSHALL MILLER, 911 North Eighth Street, Philadelphia, Pa.

MR. W. S. RUGG, Pittsburgh Athletic Club, Fifth Avenue, Pittsburgh, Pa.

MR.. JOHN P. B. SINKLER, 412 Otis Building, 112 South Sixteenth Street, Philadelphia, Pa.

NECROLOGY.

Dr. Arthur Beardsley was born at Esopus, N. Y., November 1, 1843, and died at Swarthmore, Pa., on January 29, 1917.

He studied at Bowdoin College and afterward at the Rensselaer Polytechnic Institute, at Troy, N. Y., from which institution he was graduated in 1867 with the degree of Civil Engineer.

The year following his graduation was spent as an assistant engineer in the construction of the Hoosac Tunnel, and the following year as a civil engineer and architect in Poughkeepsie, N. Y.

He then became instructor of civil engineering and industrial mechanics at the University of Minnesota, and for the two following years, 1870–'72, professor of these subjects in the University.

In 1872 he became professor of applied mathematics and engineering in Swarthmore College, which position he retained until 1898, when he was compelled to resign on account of impaired vision and was made emeritus professor of engineering.

He was a member of the American Society of Civil Engineers, the American Society of Mechanical Engineers, and a fellow of the American Association for the Advancement of Science.

He was elected a member of The Franklin Institute on April 8, 1874, and a member of the Board of Managers in June, 1894.

He served for eight years on the Committee on Science and the Arts, and was chairman of this committee in 1892.

Besides being a practical engineer of acknowledged ability, Dr. Beardsley had the qualities which rendered him a highly efficient teacher in training young men for the engineering profession.

He put the same energy and interest into his participation in the activities of the Institute, and when, in 1901, his failing eyesight rendered further service impossible, the Board of Managers expressed appreciation of his services by electing him to Honorary Membership.

G. A. H.

Richard Waln Meirs was born in Waterford, N. J., in 1866, and died in Philadelphia, April 21, 1917. Mr. Meirs was educated at the Eastburn Academy, Philadelphia, and the Freehold Institute at Freehold, N. J. He then entered Princeton University and was graduated in the class of 1888. He occupied a distinguished position in financial circles, both in Philadelphia and New York. Along with his other activities, in 1905, Mr. Meirs became manager of the Weightman-Walker estates, in which capacity he continued until his death. His interest in the liberal arts is attested by his membership in many societies.

He became a member of The Franklin Institute in 1905, and was a member of its Board of Managers since 1908.

Mr. J. J. Burleigh, Merchantville, N. J.

LIBRARY NOTES.

PURCHASES.

British Journal Photographic Almanac. 1916.

BUSHNELL, S. M., and ORR, F. B.—District Heating. 1915.

CLARK, V. S.—History of Manufactures in the United States, 1607–1860.

DUCHENE, CAPTAIN.—The Mechanics of the Aeroplane. 1915.

FINDLAY, ALEX.—Chemistry in the Service of Man. 1916.

HAMILTON, D. T., and JONES, F. D.—Advanced Grinding Practice. 1915.

HOLMS, A. C.—Practical Ship Building. 2 vols. 1916.

International Catalogue of Scientific Literature, No. 12. H—Geology. 1916.

JOHNSON, J. E., JR.—Blast-furnace Construction in America. 1917.

LYON, T. L., FIPPIN, E. O., and BUCKMAN, H. O.—Soils: Their Properties and Management. 1916.

MURRAY, A. J.—The Strength of Ships. 1916.

PERRIN, JEAN.—Atoms. (Translation from the French by D. L. Hammick.) 1916.

Reader's Guide to Periodical Literature, Supplement No. 4. 1916.

ROE, J. W.—English and American Tool Builders. 1916.

WEST, GEORGE.—Practical Principles of Plain Photo-micrography. 1916.

GIFTS.

Alabama Geological Survey, Bulletin No. 18, Preliminary Report on the Crystalline and Other Marbles of Alabama, by William F. Prouty. University, 1916. (From the Survey.)

Alpha Portland Cement Company, Alpha Cement and How to Use It. Easton, Pa., 1917. (From the Company.)

Aluminum Company of America, Aluminum Electrical Conductors. Pittsburgh, no date. (From the Company.)

American Electric Railway Engineering Association, Proceedings, 1916. New York, 1916. (From the Association.)

American Ephemeris and Nautical Almanac for the Year 1919. Washington, 1917. (From the Nautical Almanac Office.)

American Institute of Mining Engineers, Transactions, vol. liv, 1916. New York, 1917. (From the Institute.)

American Sheet and Tin Plate Company, Black Sheets and Special Sheets, and Research on the Corrosion Resistance of Copper Steel. Pittsburgh, 1916. (From the Company.)

American Society of Civil Engineers, Year Book, February, 1917. New York City, 1917. (From the Society.)

Argentina Comision Protectora de Bibliotecas Populares, Annales de la Biblioteca, Tomo x. Buenos Aires, 1915. (From the Commission.)

Brown Instrument Company, Catalogue of Brown Instruments for Measuring Temperature, Pressure, Electricity, and Speed. Philadelphia, no date. (From the Company.)

Bruce, Robert, The National Road, Baltimore and Washington to Wheeling, West Va. Clinton, Oneida County, N. Y. 1916. (From the Author.)

Bureau for the Safe Transportation of Explosives and Other Dangerous Articles. Report of the Chief Inspector, February, 1917. New York, 1917. (From Col. B. W. Dunn.)

Canada Department of Mines, Geological Survey, Memoir 88, Geology of Graham Island, British Columbia, and Memoir 94, Ymir Mining Camp, British Columbia. Ottawa, 1916–1917. (From the Department.)

Canadian Society of Civil Engineers, Transactions, vol. xxix, part ii, October to December, 1915. Montreal, 1916. (From the Society.)

Cheney Brothers, The Miracle Workers, The Story of Silk, and A Short Description of Silk and Silk Manufacture. South Manchester, Conn., 1916. (From the Company.)

Commercial Camera Company, The Photostat Book. Rochester, N. Y., no date. (From the Company.)

Delaware College, Annual Catalogue, 1916–1917. Newark, Del., 1917. (From the College.)

Dunham (C. A.) Company, Bulletins of Heating and Ventilating Specialties. Marshalltown, Iowa, 1913–1916. (From the Company.)

Edison Lamps Works of the General Electric Company, A Handbook on Incandescent Lamp Illumination. Harrison, N. J., 1916. (From the Company.)

Fellows Gear Shaper Company, Commercial Gear Cutting, The Gear Shaper Cutter, The Helical Gear Shaper, The Involute Gear, and The Stub-tooth Gear. Springfield, Vt., 1909–1916. (From the Company.)

Foster Machine Company, The Foster No. 1 B Universal Turret Lathe with Tools and Attachments. Elkhart, Ind., no date. (From the Company.)

General Education Board, Report of the Secretary, 1915–1916. New York City, 1916. (From the Board.)

General Fireproofing Company, The Fireproofing Hand-Book, Fifth Edition, 1916. Youngstown, 1916. (From the Company.)

Great Britain Board of Trade, Boiler Explosions Act, 1882, Thirty-third Annual Report upon the Working of the Act. London, 1916. (From the Manchester Steam Users' Association.)

Haldane, John Scott, Organism and Environment as Illustrated by the Physiology of Breathing. New Haven, 1917. (From Yale University.)

Hobart College Catalogue, 1916–1917. Geneva, N. Y., 1917. (From the College.)

Indiana Department of Geology and Natural Resources, Fortieth Annual Report, 1915. Indianapolis, 1916. (From the Department.)

Institute of Metals, Journal, vol. xvi, No. 2, 1916. London, 1916. (From the Institute.)

International Clay Products Bureau, The Clay Pipe Book. Kansas City, Mo., 1917. (From the Bureau.)

Iron and Steel Institute, Journal, vol. xciv, No. 11. London, 1916. (From the Institute.)

John Crerar Library, A List of Books on the History of Science. Supplement, December, 1916. Chicago, 1917. (From the Library.)

Leland Stanford Junior University Library, List of Serials. Stanford University, Calif., 1916. (From the Library.)

Lyman, Benjamin Smith, Vegetarian Diet and Dishes. Philadelphia, 1917. (From the Author.)

Massachusetts Institute of Technology, President's Report, 1917. Cambridge, 1917. (From the Institute.)

Mississippi State Geological Survey, Bulletin No. 13, Marls and Limestone of Mississippi, by William N. Logan. Jackson, 1916. (From the Survey.)

Municipal School of Technology, Journal, vol. viii. Manchester, 1914. (From the School.)

Murphy Iron Works, Catalogue No. 25, The Murphy Automatic Smokeless Furnace. Detroit, 1912. (From the Works.)

Music Trades Company, The Piano and Organ Purchaser's Guide for 1917, Twenty-first Annual Edition. New York, 1917. (From the Company.)

Mysore Government, Meteorological Department, Report on Rainfall Registration in Mysore, 1915. Bangalore, 1916. (From the Department.)

New York Public Library, Handbook. New York, 1916. (From the Library.)

New York State Library, Ninety-eighth Annual Report, 1915. Albany, 1917. (From the Library.)

New Zealand Government Statistician, Statistics of the Dominion, 1915, vol. i, Blue Book, Population and Vital Statistics, Law and Crime. Wellington, 1916. (From the Government Statistician.)

Northrup, Edwin F., Laws of Physical Science. Philadelphia, 1917. (From the Author.)

Oberlin College, The Annual Catalogue, 1916–1917. Oberlin, Ohio, 1917. (From the College.)

Ohio Brass Company, Steam Road Electrifications. Mansfield, 1917. (From the Company.)

Ontario Bureau of Mines, Twenty-fifth Annual Report, 1916, vol. xxv, part iii, The Geology of Kingston and Vicinity, by M. B. Baker. Toronto, 1916. (From the Bureau.)

Pennsylvania Commission to Investigate the Increase in the Cost of Anthracite Coal, Report, 1915. Harrisburg, no date. (From the State Librarian.)

Pennsylvania Department of Forestry, Report for the Years 1914–1915. Harrisburg, 1916. (From the State Librarian.)

Pennsylvania Superintendent of Public Instruction, Report for the Year Ending July 3, 1916. Harrisburg, 1916. (From the State Librarian.)

Pennsylvania Superintendent of Public Printing and Binding, Annual Report for the Year Ending June 30, 1915. Harrisburg, 1916. (From the State Librarian.)

Philadelphia City Councils, Manual, 1917. Philadelphia, 1917. (From the Chief Clerk, Select Council.)

Philadelphia College of Physicians, Transactions, Third Series, vol. 38. Philadelphia, 1916. (From the College.)

Pike Manufacturing Company, Sharpening Stones, History and Development. Pike, N. H., 1915. (From the Company.)

Powell (William) Company, Catalogue No. 10, Third Edition, Dependable Engineering Specialties. Cincinnati, 1916. (From the Company.)

Robbins & Myers Company, Bulletins Nos. 105, 107, 109, 111, 113, 115, 121, 123, 125, 127, and 129, descriptive of Motors and Generators. Springfield, Ohio, 1915–1917. (From the Company.)

South Australia Government Geologist, Annual Report, 1915. Adelaide, 1916. (From the Government Geologist.)

Springfield (Mass.) Water Commissioners, Forty-third Annual Report, 1916. Springfield, 1917. (From the Commissioners.)

Syracuse University, Catalogue, 1916–1917. Syracuse, N. Y., 1917. (From the University.)

Toledo Pipe Threading Machine Company, Toledo Pipe Threading Hand Book. Toledo, Ohio, no date. (From the Company.)

United Engineering and Foundry Company, Bulletins A, B, F, I, M, P, R, and S1. Pittsburgh, 1916–1917. (From the Company.)

United Motors Corporation, Prospectus. New York, no date. (From the Corporation.)

U. S. Naval Academy Graduates' Association, Register of Graduates, June, 1916. Annapolis, Md., 1916. (From the Association.)

Westinghouse Lamp Company, The Lighting Dictionary, Salesmen's Lamp Handbook Series No. 2. New York, no date. (From the Company.)

White Fuel Oil Engineering Corporation, The White Low-pressure Mechanical Oil-burning System, and Instructions for Running the System. New York, 1916. (From the Corporation.)

Williams Tool Company, Catalogue of Tools. Erie, Pa., no date. (From the Company.)

Witte Engine Works, Catalogue No. 47, How to Judge Engines. Kansas City, Mo., 1916. (From the Works.)

BOOK NOTICES.

THE INTERNATIONAL MILITARY DIGEST ANNUAL for 1916. Col. C. De W. Willcox and Lieut.-Col. E. R. Stuart, Editors-in-Chief, with the coöperation of 31 Associate Editors. New York, Cumulative Digest Corporation, 1917. 630 pages, 8vo. Price, $5.

The International Military Digest is a monthly periodical containing abstracts of articles of military interest appearing in current literature published at home and abroad. The present volume is the cumulation of the monthly issues for the year 1916. The abstracts, with which are given the title of periodical, author, date, and number of words, give a very satisfactory *résumé* of the original articles. Obviously at this time, when the entire civilized world is either at war or preparing for war, a condensed account of current military activities is of rare interest alike to layman and expert. The work is not merely a collection of the monthly issues of the *Digest;* the articles are rearranged in classified alphabetical order, with many cross-references, an arrangement which materially adds to its value.

LUCIEN E. PICOLET.

GAS CHEMISTS' HANDBOOK. Compiled by Technical Committee, Sub-Committee on Chemical Tests: C. C. Tutwiler, Chairman; A. F. Kunberger, Editor. New York: American Gas Institute, 1916. 345 pages, contents and index, illustrations, 8vo. Price, $3.50.

This is a collection of analytic procedures for use by gas chemists, with some accessory matters, such as tests of construction materials, alloys, and lubricating oils. Many of the methods are in tentative form, as the committee has not yet been able to determine their value absolutely, but the procedures for coal, coke, cement, iron, and steel are regarded as substantially established. The work is well printed, liberally illustrated, and correct chemical terms are mostly used. The reviewer regrets to note, however, such absurd terms as "benzol" and "nitrobenzol." Surely the chemists who are engaged in American laboratories know enough chemical nomenclature not to be confused by the title "benzene," and there is no excuse for retaining a highly erroneous term.

The reviewer notes two typographic errors: on page 171, "Effervescent" should, it seems, be "efflorescent" and on page 175 the formula for sodium picrate is wrong.

HENRY LEFFMANN.

PUBLICATIONS RECEIVED.

U. S. War Department: Annual Reports, 1916: Vol. 1, Secretary of War, Chief of Staff, The Adjutant-General, Inspector General, Judge-Advocate General, Quartermaster-General, Surgeon-General, Chief of Ordnance, Chief Signal Officer, Chief of Militia Bureau, Chief of Coast Artillery, Military Academy, Military Parks; Vol. 2, Chief of Engineers; Vol. 3, Chief, Bureau of Insular Affairs, Governor of Porto Rico, Philippine Commission. 3 volumes, plates, maps, diagrams, tables, 8vo. Washington, Government Printing Office, 1916.

Preliminary Mathematics, by Prof. F. E. Austin, B.S., E.E. 169 pages, 12mo. Hanover, N. H., Author, 1917. Price, $1.20.

Manila Bureau of Science, Division of Mines: The Mineral Resources of the Philippine Islands for the Year 1915. 39 pages, map. 8vo. Manila, Bureau of Printing, 1916.

Ontario Bureau of Mines: Twenty-fifth Annual Report, 1916. The Geology of Kingston and Vicinity, by M. B. Baker. 71 pages, 8vo. Toronto, King's Printer, 1916.

University of Illinois: A Brief Prepared for the Governor and the General Assembly of the State of Illinois Concerning the Work of the College of Engineering and the Engineering Experiment Station of the University of Illinois and a Statement of Their Needs for the Two Years Beginning July 1, 1917. 28 pages, illustrations, plates, quarto. Urbana, 1917.

U. S. Bureau of Mines: Bulletin 119, Analyses of Coals Purchased by the Government During the Fiscal Years 1908–1915, by George S. Pope. 118 pages. Technical Paper 82, Oxygen Mine Rescue Apparatus and Physiological Effects on Users, by Yandell Henderson and James W Paul. 102 pages, illustrations, plates. Technical Paper 137, Combustion in the Fuel Bed of Hand-fired Furnaces, by Henry Kreisinger, F. K. Ovitz, and C. E. Augustine. 76 pages, illustrations, diagrams, plates. Monthly Statement of Coal-mine Fatalities in the United States, January, 1917; List of Permissible Explosives, Lamps, and Motors Tested Prior to February 28, 1917, Compiled by Albert H. Fay. 4 Pamphlets, 8vo. Washington, Government Printing Office, 1916–1917.

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A Clock of Precision. C. O. BARTRUM. (*Proceedings of the Physical Society of London*, vol. xxix, pt. ii, p. 120, February 15, 1917.)—In designing a pendulum clock, provision has to be made for automatically counting the swings and for maintaining the arc of the pendulum. In general practice, these are effected by some form of release, actuated by the pendulum itself, or of contact with the pendulum whereby the vibrations are recorded and the signal given to the motive mechanism that the pendulum is in the position to receive its impulse. Such methods are objectionable so far as the disturbance thereby caused to the free swing of the pendulum is constant. In practice this is impossible.

The principal feature of the author's arrangement is the employment of a "slave" clock to do the great part of the work, leaving the master pendulum no function beyond that of controlling the rate of the other. The master pendulum swings freely except for a short period (about one-fifth of a second) every minute, during which it receives an impulse from a small falling wheel electromagnetically released by the slave clock. At the end of its fall the impulse mechanism closes a second circuit and is restored to its initial position. These two electric circuits also energize parts of the mechanism in the slave clock by which the latter is kept in time with the master pendulum. The lagging of correction behind error, with the resulting periodic fluctuation in the rate, is reduced almost to the vanishing point by the introduction of a "negative backlash" in the control mechanism.

CURRENT TOPICS

Steels Suited to Aeronautical Purposes. G. A. RICHARDSON. (" Proceedings of the Aeronautical Society of America," *Iron Age*, vol. 99, No. 13, p. 778, March 29, 1917.)—In considering steels available for aeronautical purposes, the subject logically divides itself according to the requirements of structural parts and members, as follows: Stay wires, struts, body parts, etc., power plants and transmission parts, protective armor for military planes, aeronautical instruments, and miscellaneous equipment.

Much attention has been given to the results of tests on the best forms of terminal connections as having bearing on the quality of stay wire that can be satisfactorily used. The original object in using wires for stays was to make it as strong as possible so as to reduce weight. This resulted in a wire so hard and strong that difficulty was experienced in forming the eye and bend for the terminal connection without breaking the wire. The final results of tests to date are that the best wire to use is that which is sufficiently strong and serviceable to permit some reduction in weight, but which combines high tensile strength, toughness, and ductility as well. Carefully-made, high-grade carbon steel affords to-day the most reliable and flexible material for the purpose. Protection against corrosion is of the greatest importance; galvanizing and tinning should always be used in conjunction with a protective coating of paint and not by themselves. Struts should also be designed for minimum weight with maximum strength. This end is best secured by the adoption of cold-drawn chrome-nickel-steels. A protective coating is essential with these members also.

For the engine it is desirable to use steels that do not corrode easily, and for such parts as cylinders that will not be injured by overheating, a condition especially possible in the event of a cooling plant giving out. Professor Lucke, of Columbia University, recommends the use of ordinary, comparatively low carbon steel, cold drawn to shape. By this method of manufacture, a cylinder of uniform wall thickness can be obtained of satisfactory thermal conductivity and possessing at the same time the requisite toughness to enable it to wear well. He objects to the use of alloy compositions, on the ground that they will be injured by overheating and that ordinary steel answers all purposes. Twenty-five per cent. nickel steel is not open to this objection. It is also quite resistant to corrosion and is non-magnetic. Piston and connecting rods can follow automobile practice. Crankshafts and camshafts may be made of chrome-nickel-steel, the latter case-hardened. For valve parts, three per cent. nickel-steel, because of its resistance to corrosion, low coefficient of expansion, and other physical properties, is recommended. Cams and tappets have been made of special alloys, but carbon steel also gives good results. Unquestionably there are important advantages to be gained by the use of metal propellers, and, as a solid section seems desirable, it seems quite certain that some light-weight alloy will prove superior to steel.

The design in the power and transmission plants should be made first, and then, if necessary, the elastic limit increased by the use of chrome-nickel-steel. On short flights the engine and transmission parts weights are of more importance than the amount of lubricating oil, while on long flights the increase in weight by the use of cast-iron cylinders and pistons will very likely be more than offset by the saving in weight of lubricating oil. When it comes to the question of aeroplanes for military use it is of the greatest importance that the passengers and vital parts of the machine be protected as far as possible by armor plate. It is impracticable to use armor plate of sufficient thickness to withstand all kinds of shell fire on account of the weight. On the other hand, however, it is possible to secure some remarkably satisfactory results with very thin plate.

Nitro-starch as an Explosive. S. S. SADTLER. (*Metallurgical and Chemical Engineering,* vol. xvi, No. 7, p. 361, April 1, 1917.)—The application of high explosives to mining and general commercial purposes may be said to date from the discovery of Nobel that nitroglycerin could be absorbed in kieselguhr and then handled with a sufficient degree of safety to warrant its use. The product was called dynamite, but this name now applies broadly not only to nitroglycerin absorbed by other inert materials, like sawdust, mica-powder, etc., and other mixtures as well, but also it applies to various high explosives containing no nitroglycerin. At present there are an indefinite number of chemical mixtures aiming to meet the different working conditions. By the solution of gun-cotton or nitrocellulose in nitroglycerin (in which it readily dissolves, forming a jelly-like mass) we obtain blasting gelatine and gelatine dynamites and mixtures of these with other ingredients. Gun-cotton (or the higher cellulose nitrate) has not been found applicable by itself for the field of commercial blasting and mining explosives, except for submarine blasting, where the compressed gun-cotton finds a use, as it is too bulky in comparison to its weight for other work.

An earnest effort had been made for some time to find a satisfactory substitute for nitroglycerin dynamite, but without success until recently, when great improvements were made in the manufacture of nitro-starch and a suitable container found for its use. Starch, which has an analogous chemical composition to cellulose and forms corresponding nitrate esters, was early suggested as the basis of a high explosive, having all the advantages of cotton without its bulk or higher cost. For blasting, this material has great many advantages. It cannot be exploded except by exploding a cap in contact with it, it gives off no bad fumes, is non-freezing, and appears to have good stability, a quantity stored for ten months showing no deterioration. One of the chief points of merit in the use of nitro-starch is its cost. As there is no special difficulty in its manufacture, it can readily be seen that, being made from a base costing 2⅛ to 2¼ cents a pound, as compared with glycerine at 30 to 60 cents a pound, or cellulose rising to 10 cents, there is great economy in its use. Quite apart from the cost of bases, but for reasons of simplicity of handling and time of nitration, it promises to be more easily and economically manufactured than nitrocellulose.

Explosions in Oxygen Tanks. ANON. (*Metallurgical and Chemical Engineering,* vol. xvi, No. 7, p. 402, April 1, 1917.)—The attention of the Bureau of Mines has recently been directed to a series of explosions of oxygen made by the electrolytic process in which life has been lost as a result of hydrogen being mixed with the oxygen. It has been found that this is due to improper design in the manufacturing apparatus (*i.e.,* to the cells and electrical connections); to insufficient safeguards connected with the electric apparatus, the polarity suddenly and unexpectedly shifting; to the manufacture of oxygen without frequent analyses, and to incompetent and ignorant attendants. Unfortunately certain makers of oxygen-building apparatus have advertised that any laborer can take care of their apparatus. It is believed that the manufacture of electrolytic oxygen can be carried on in a manner to make it perfectly safe. In fact, there must be over nine per cent. of hydrogen with the oxygen to make an explosive mixture. Nevertheless, certain tanks from one batch caused three widely-separated explosions in California, killing seven men in all, and an analysis of gas from a tank filled at the same time showed that it contained over 50 per cent. of hydrogen.

Census of Mining Engineers and Metallurgists in the United States. VAN H. MANNING. (*Circular letter, U. S. Bureau of Mines,* April 5, 1917.)—The Bureau of Mines, in coöperation with the American Institute of Mining Engineers and the American Chemical Society, has undertaken a census of mining engineers, metallurgists, and chemists with a view of ascertaining the qualifications of each and the line of work in which each can be of the most service to the country in time of emergency. The classification will embrace 27 specific groups of industrial chemists, 16 groups of engineering specialists, and 15 groups in the metallurgical field. By such minute classification the Bureau will be in a position to furnish on short notice the names of specialists for service under the classification, so that in case of necessity these technical men can be available to industrial plants where they would be of most assistance to the country. European experience has shown that nothing is more important in time of national emergency than a knowledge of the qualifications and experience of expert technical men.

Industrial Value of Metallography. ANON. (*The Iron Trade Review,* vol. ix, No. 12, p. 673, March 22, 1917.)—Thirty years ago metallography as a science was almost unknown, and only within the last twenty years has it received serious consideration by manufacturers and consumers as a valuable means of metal testing. The development of metallography in the early years of its history was slow, but the advances in the past five years have probably exceeded all those previously made. At the present day metallography is taught in almost all technical and engineering schools of university grade, and methods of metallographic testing find wide use in the metallography of iron and steel and the non-ferrous alloys as well.

Metals and alloys owe their industrial importance to their physical properties in a large measure, and it is in testing and determining these physical properties that the methods of metallography have come to be almost indispensable. For instance, the great advances in the production of high-quality rail steel could scarcely have been brought about without the aid of the new science. The physical properties of metals and alloys are dependent upon their proximate structural compositions rather than upon their ultimate chemical compositions, and it is in revealing the former that the value of metallographic testing lies. The methods of chemistry furnish information of the utmost value, but they do not make possible much knowledge concerning the structure and physical constitution of substances.

Noiseless Cotton Gear-wheels. ANON. (*Scientific American,* vol. cxvi, No. 12, March 24, 1917.)—Steel gears and pinions are among the noisiest creations of man. By providing steel gear trains with cotton-ball pinions, the noise is eliminated, much to the comfort and health of the operatives, and greater efficiency and increased production secured. These new pinions are remarkable for strength, elasticity, and toughness. They will outwear iron or brass and are proof against damage by water, oil, dryness, or temperature changes. They have been adapted to all kinds of machines, from automobiles to turbine engines, and because of their durability and noiseless operation they are applicable to numerous types of machine tools. They likewise find a wide use in spinning and weaving machinery.

Only the highest quality of cotton is used in the manufacture of these gears, and it must be thoroughly cleaned. It is received at the factory in the usual rolls as it comes from the roving frames. These are rewound on cylinders and compressed by hydraulic pressure into " blanks " for the gear-cutting machines. These blanks are usually formed with an outer covering of steel, no metal bushing being used in the bore. The cotton filler is compressed under hydraulic pressure of several tons per square inch of side surface, and held in compression by the steel shrouds or side plates by threaded studs. In the large gears having special hubs, economy of manufacture requires the use of a metal centre and a separate cotton rim. The blanks impregnated with oil are cut on the usual gear shapers or with rotary cutters.

Making Milk Bottles of Paper. ANON. (*Scientific American,* vol. cxvi, No. 11, p. 275, March 17, 1917.)—A rather general movement has taken place toward the abolishment of the well-nigh universally used glass milk bottle. When, many years ago, the glass bottle supplanted the customary can-and-dipper method of serving milk, it was looked upon, and doubtless was, an important step in improving sanitary conditions of milk supply. Now doctors and health experts condemn the glass bottle as a pernicious germ carrier. They are demanding that destructible bottles be used for the distribution of milk in the homes of dairy patrons, so that they cannot be returned to the dairy to be refilled and sent out another time, laden perhaps with germs picked up in the first home.

In that connection it is interesting to note that a new machine has just been perfected by a western inventor that will manufacture paper milk bottles at the rate of 5000 an hour. It is a radical departure from previous contrivances in that it manufactures the new bottles from wood pulp rather from a finished paper, as is done in the case of practically all the containers on the market to-day. This feature insures a very low cost of the product, well within the reach of the average milk dealer. It is claimed that the new paper bottle is cheaper in the long run than the common glass bottle.

The process of manufacture is simple. A steel core is dipped into a tank of raw pulp, and by means of four clamps the pulp is pressed around the core, forming a seamless body, much as a sculptor presses soft clay into shape with his hands. During this operation the bottle revolves three complete times, the clamps pressing at every one-third turn. Thus the paper and the bottle are formed in one and the same operation. The bottle next passes through a drier and over a stencil cut which prints on it the name of the dealer, the capacity of the bottle, etc. It is then removed from the core by a steel hand and deposited on a belt conveyor, which delivers it to a machine which crimps on the bottom and top. The bottle is then given a paraffin bath that renders it impervious to liquid or acid, and is automatically packed in dust-proof cartons for delivery to the dealer. The operation is continuous, and it takes about eight minutes to convert the raw pulp into the completed milk bottle. Less than half an ounce of wood pulp is required to make one of the new sanitary bottles, and one ton of pulp will produce 60,000 containers. Three men only are required to operate the machine, and from beginning to end the bottle is handled only by steel fingers, so that the apparatus meets all sanitary requirements.

Plastic Cements. J. B. BARNITT. (*Metallurgical and Chemical Engineering,* vol. xvi, No. 6, p. 321, March 15, 1917.)—A working knowledge of the correct mixtures and proper application of plastic cements is deemed so essential to successful chemical engineering operations that an effort has been made to collect and classify a few of the more valuable formulas and suggestions gained both from experience and current literature.

It is to be understood that plastic cements cover that range of adhesives which are used to secure joints and connections between like and unlike material of more or less permanent character. Physically speaking, plastic cements consist of a vehicle in which are suspended or dissolved solids of such nature that they are resistant to the gases and liquids coming in contact with them. In some cases the constituents of the cement react with each other or with the surfaces to which they are applied, thus forming a more strongly adhering mass.

One of the principal precautions to be observed in the application of a cement is the condition of the material to be joined. All connections should be properly fitted together with flanges or exposed flat surfaces as nearly coincident as possible. The cement should never be depended upon to do what the pipes or other portions of the apparatus should do; its function is to cement or seal, and nothing more. In most cases one part of the fitting should overlap the other so as to make a small amount of the cement effective. Cement for a joint of this type should be of such a nature that it may be quickly applied; that is, effective while in place and easily removed when desired. An excess of cement should always be avoided to prevent shrinkage cracks and leaks.

The general methods of plastic cement application are varied to suit special cases, as follows: (*a*) Heating the composition to make it plastic. (*b*) Heat applied to the surface to be cemented. (*c*) Application of the cement with water or a volatile solvent, depending upon the evaporation of the solvent for drying or setting. (*d*) Moistening the surfaces to be cemented with water, oil, etc. (the vehicle of the cement itself. (*e*) Application of the cement in workable condition, setting taking place by chemical reaction, hydration, or oxidation. The application of the following materials as plastic cements is noted: (1) plaster-of-Paris; (2) hydraulic cement; (3) clay; (4) lime; (5 asphalt or pitch; (6) rosin; (7) rubber (8) linseed oil; (9) casein and albumen; (10) silicate of soda and oxychloride cement; (11) flour and starch; ((12) miscellaneous materials.

Authoritative Data on the Properties of Metals and Alloys. S. W. STRATTON. (*Circular letter, U. S. Bureau of Standards,* March 24, 1917.)—The Bureau is undertaking to compile the present state of knowledge and practice concerning the numerical values used by engineers and others for the properties of metals and alloys, with a view to making generally available the most acceptable values of these constants and also as a basis for further experimental investigation. A form sheet is furnished containing the various items required. These cover the mechanical, thermal, electrical, and optical properties of value to the investigator and engineer. A sheet of instructions for compiling the table with an illustrative filled-out form for commercial electrolytic copper is included. This contains a list of the alloys on which data are particularly desired.

Closely-drilled Gas Fields Short-lived. ANON. (*U. S. Geological Survey, Press Bulletin* No. 313, March, 1917.)—One of the most important problems confronting the gas-producing industry is that of determining the smallest number of wells capable of removing most economically all the gas under a given tract of land. So many complex factors enter into this problem that few systematic attempts have been made to solve it, and gas operators have in general been content to accept rough estimates of the number of wells that should be drilled per unit of area. In some localities it is held that only one well should be drilled to each 800 acres; in others it is customary to drill a well in each 20 or 40 acres. With present knowledge the number to be drilled must be to some extent a matter of opinion, and it is very doubtful whether any limit can be fixed that will be applicable to all fields.

Those who are familiar with the gas industry have long realized that a closely-drilled field is short-lived, and that in most pools the later wells are less likely to be profitable than the earlier ones. Few operators, however, have attempted to analyze the reasons for these conditions, and most of the business men and others who are occasionally induced to take a " flyer " in gas producing seem to be ignorant of the existence of them. Hence, in many eastern gas fields there are more wells than are necessary or profitable, and in some fields the wells are crowded so closely that many of them have never produced enough gas to pay for themselves.

A study of the available records of rock pressure and flow of wells in the Cleveland field indicates that the decline of rock pressure in the older wells is a valuable criterion in controlling new development. Probably in most fields the wells that are brought in after the general pressure has declined to one-third of its original amount are unprofitable, and in many fields this point may be reached when the pressure has declined only one-half.

The geology of the Cleveland field in relation to the accumulation of the gas has recently been investigated by the United States Geological Survey, Department of the Interior, and is discussed in Bulletin 661-A, entitled "The Cleveland Gas Field, Cuyahoga County, Ohio, with a Study of Rock Pressure," by G. Sherburne Rogers. A copy of this report may be obtained on application to the Director of the Geological Survey, Washington, D. C.

Useful Minerals of the United States. ANON. (*U. S. Geological Survey Press Bulletin,* No. 312, March, 1917.)—A new edition of the popular work entitled, "Useful Minerals of the United States," is being published by the United States Geological Survey, Department of the Interior, as Bulletin 624. It is a revised, enlarged, and up-to-date edition of a bulletin that was issued about two years ago. A large edition of that bulletin was published, but it soon became exhausted, and several thousand applications for it were received after the edition printed had been distributed.

Bulletin 624 notes the enormous increase in development, production, and value of the useful minerals of the country during the last 25 years and many of the changes and discoveries that have taken place in the mineral industry. It aims also to supply the rapidly growing demand for information regarding our mineral resources and the special demand occasioned by the European War.

Besides giving several thousand new localities of mineral deposits and adding more than 160 new mineral names to the glossary, the new bulletin furnishes considerable additional information concerning certain minerals, especially the uranium and vanadium minerals found in the high plateau region of the West. The present bulletin, like the earlier work, gives concisely, by states and counties, the location of the principal deposits of useful minerals and includes a glossary showing the composition and character of each mineral and the location of its principal deposits. It gives also the principal uses of each mineral, which were not stated in the first edition. As a mineral directory, it promises to be of service to scientific bureaus and educational institutions that prepare replies to the numerous inquiries of the general public on subjects connected with what may be called commercial mineralogy, as well as to the prospector, miner, manufacturer, and business man and the student of economic conditions.

Flexible Gear for Ship Propulsion. L. R. EMMET. (*General Electric Review,* vol. xx, No. 3, p. 238, March, 1917.)—Perhaps the most serious obstacle to the adaptation of reduction gears to marine turbines has been the difficulty of securing the accurate contact conditions between the teeth of the gears essential to efficient transmission, durability, and freedom from breakdown, and much study and costly experiment have been expended in the effort to insure this end. An ingenious and most attractive method, in its simplicity of overcoming contact difficulties encountered in the wide-face high-speed gears employed with ship-propulsion turbines, has been devised by Karl Alquist, of the General Electric Company. To secure quiet running, helical gears are ordinarily employed for this service. These are mounted on the shaft in pairs with equal and opposite helical angles for the purpose of neutralizing the axial component of the tooth pressure, and are kinematically equivalent to the time-honored "herring-bone" gears used in rolling-mill practice.

When the gears are solid and inflexible, there is always a tendency for the stress at the loaded end of the pinion to be increased by torsional deflection. There is also a tendency to inequality of stress upon the tooth surface from lateral deflection. These deflection troubles are overcome in the Alquist gear by making the relatively large driven gear in several sections, solidly bolted together at the hub but separated from each other at all other points, so that if any undue pressure tends to occur at the tooth-surface of a section a slight deflection of the thin and elastic section immediately acts to maintain the pressure at its normal value. To insure that these sections shall be in proper relation to each other, the gear blanks are provided with a contact surface at the periphery as well as at the hubs, assembled and cut as a solid gear. After the teeth have been formed the contact surface is cut away, leaving the teeth in as perfect alignment as if cut from a solid blank.

Many sets of this gearing have been built and experimented with exhaustively under a variety of conditions, and by these experiments certain standards of practicability have been established and extensive commercial developments undertaken. Gearing of this character has been applied to about 72 sets of turbo-electric generators of various types and contracts have been closed for the machinery for the propulsion of seventy ships aggregating 215,000 horsepower. Some of these electric generating sets have been in service one and one-half years, and about seven of the ship sets are in service, some of them having made many long voyages. Among these are the high-pressure cruising units of the battleship *Nevada*, which have given very satisfactory results. Among the ship equipments not yet completed are included the propelling machinery for *Destroyer No. 69*, built at Mare Island, and the new propelling machinery for scout cruiser *Salem*. In all this practical experience no case of trouble with the gearing has developed and no appreciable deterioration of gears has been observed.

Vacuous Arc Lamps. ANON. (*Electrical World*, vol. lxix, No. 6, p. 270, February 10, 1917.)—An arc lamp operating in a vacuum chamber, in which the electrodes are fixed and non-distintegrating, constitutes patent No. 1,208,597 to George M. J. Mackay, of Schenectady, N. Y. The essential condition of operation appears to be that one electrode be incandescent, and for this reason two conductors are led into the top of the envelope, whereas only one lead is provided for the anode. The device comprises an envelope consisting of glass, such as low-expansion or sodium-magnesium borosilicate glass. The cathode consists of highly refractive material having a melting-point exceeding at least 2000° C., such, for example, as tungsten, tantalum, carbon, or the like. The anode consists of conductive material—for example, tungsten, carbon, or other solids—but in some cases a liquid such as mercury may be used.

The globe is first evacuated and then filled with a suitable gas at considerable pressure. Monatomic gases of the argon group, also nitrogen and carbon monoxide, may be used. The gaseous pressure will more usually approach atmospheric pressure in order of magnitude. In a device used for rectifying alternating current at low voltages, argon at a pressure of about 5 to 12 centimetres of mercury is found suitable. With an envelope containing a filling of nitrogen, phosphorus pentoxide is preferred for absorbing water vapor and other gaseous impurities. In devices filled with a monatomic gas (such as argon, neon, krypton, xenon, or helium), calcium magnesium, or one of the related metals is preferable. By the use of a gas-absorbing chemical agent, the potential drop or loss is reduced to one-half, or even less.

To give specific illustrations, an incandescent cathode arc, carrying about 6 ampères, when filled with argon purified by ordinary methods, has an arc drop of about 30 to 40 volts. When the envelope contains a small quantity of phosphorous pentoxide, as above described, the arc drop is reduced to about 10 volts. Similarly a 6-ampère neon tube containing, at a pressure of about half an atmosphere, neon gas purified by the usual methods, has an arc drop of about 50 volts. The same tube, when provided with metallic calcium acting to purify the gas *in situ* in the manner above described, has an arc drop of about 20 volts.

Printing Plates from Phenol Resin Compounds. L. V. REDMAN and W. F. P. BROCK. (*Journal of Industrial and Engineering Chemistry,* vol. 9, No. 4, p. 388, April, 1917.)—The growth of syndicate work in illustrated advertising, comic supplement and "filler" for our 30,000 American newspapers has created a need for material that will lend itself to the rapid production of plates in manifold. The plate requires to be produced rapidly and inexpensively, and must be of such a quality as will print clearly on the cheap sheet used by daily papers. For this purpose celluloid compounds have been used with some success. Shellac has also been tried, and vulcanized rubber has been suggested, but neither commercially applied.

A satisfactory mould in every way can be made from the phenol moulding compounds. A sheet of the plastic phenol moulding compound is placed on a hot plate until the sheet has heated through and becomes soft and pliable. The original zinc etching is then placed on the warm plastic sheet and pressed. The pressure is raised gradually to about 2000 pounds per square inch. The mould formed in this way has generally a thickness of 1/16 to 1/32 of an inch. After cooling the hard plastic sheet has on its face a negative of the original zinc etching. On this negative mould another plastic sheet is laid and a positive printing plate is produced. As the plastic sheet and mould would naturally weld together in the hot press, various methods are used to prevent the plate sticking to the negative. A layer of oiled paper, thin metal, talc dust, etc., between the mould and cast have proved satisfactory. The ordinary newspaper cut is made with a 100-mesh screen, but it has been found possible to reproduce plates made with a screen of 150-mesh. The weight of the moulded plate is one-sixth the weight of the corresponding zinc etchings, and contributes a saving in shipping cost equal to the original cost of the plate.

Electric Activity in Ore Deposits. ANON. (*U. S. Geological Survey Press Bulletin,* No. 315 April, 1917.)—Accomplisments in electric science have far surpassed anything that men would have dared to predict in the early days of its development, yet certain prophecies in regard to it have remained unfulfilled. Among these are the suggestions of some geologists that electric phenomena might play an important part in the formation of ore deposits and that electric methods might be utilized in prospecting for ore bodies. Both these suggestions, in the light of the growing knowledge of ore deposits and of electricity, appear to be illusions. It is now clear that the great causes of ore deposition are not electric in the ordinary sense and that the electric currents generated in ore deposits are far too small to aid a prospector in discovering ore by their influence on a galvanometer or other electric apparatus held in his hands.

If, however, electricity is denied a leading part in the formation of ore deposits, its action cannot be excluded entirely. It is well known that many chemical reactions are capable of developing measurable electric currents, and it should therefore be expected that in places where chemical action is in progress in ore deposits to-day electric activity should also be detectable. This has indeed been shown to be the case by several experimenters, and minature batteries can be formed with water for the battery fluid and certain metallic minerals common in ore deposits as the poles. Bulletin 540, entitled "Electric Activity in Ore Deposits," by Roger C. Wells, recently issued by the United States Geological Survey, records a series of careful measurements of the electric potentials developed when various metallic minerals common in ore deposits are in contact with water or with solutions of various salts. Mr. Wells concludes that the character of the solutions has fully as great an influence on the electric activity developed as the nature of the metallic minerals, and that in general acid and oxidizing solutions give the highest potentials and alkaline and reducing solutions the lowest. Economic geologists have long recognized that the solutions in the upper oxidized portion of many ore deposits are acid and oxidizing, while farther down they become neutral or alkaline. Whether such variations and the electric differences dependent upon them are sufficient to cause an appreciable electric current to flow from the upper part of an ore deposit to a lower part or *vice versa* is still an open question. Surely such action, if it exists, is of relatively minor importance in controlling ore deposition, the main factor being the actual movement of metal-bearing solutions from one place to another. Measurements of electric potential can, however, be quickly and easily made and may prove very useful in indicating the direction and intensity of the chemical reactions of which they are one expression.

The Fixation of Nitrogen. J. E. BUCHER. (*The Journal of Industrial and Engineering Chemistry,* vol. 9, No. 3, p. 233, March, 1917.)—A process for the fixation of nitrogen has been developed, differing primarily from all those now in commercial use in fixing nitrogen, in the form of alkali cyanides instead of in the form of oxides of nitrogen, calcium cyanimide, nitrides, or ammonia. It is further characterized by operating at very moderate temperatures, such as 900 to 950° C., so that it is not dependent upon cheap electric power, and, because of this moderate temperature, it can be operated in iron retorts. It is of the utmost simplicity, uses iron, which is the cheapest metallic catalyzer, and does not require pure materials, such as nitrogen, but can use air or producer gas just as well. It requires no special apparatus and can be operated at once with what can be found in practically every manufacturing community. It does not require skilled labor to operate it, and it is preëminently a method that can be installed quickly in an emergency for the preparation of cyanides, ammonia, and nitric acid.

The process is based upon the property that nitrogen will combine with an alkali and carbon in the presence of iron as a catalyst and produce cyanides. That is, by heating a mixture of carbonate of soda and powdered coke in a furnace and passing air over the mixture, cyanide of soda is produced with the iron uncombined. No electric power is needed, no heavy outlay, no costly materials; the whole process can be carried out anywhere at apparently very low cost. By leading waste gas (carbon dioxide) from a furnace into a solution of cyanide of soda, urea is produced, a compound which bids fair to yield remarkable results as a fertilizer.

The cyanide of soda under influence of an electric current separates into metallic sodium, for which there is a large demand in chemical industry, and cyanogen. The cyanogen is rapidly absorbed in hydrochloric acid and becomes oxamide. This contains nearly one-third nitrogen in combination and is nearly insoluble, so that it would not be washed away from the soil by rains, and it also should make an ideal fertilizer. The use of urea or oxamide as fertilizer has never been considered in the past on account of its cost.

Earth, Sand-clay, and Gravel Roads. ANON. (*Bulletin No. 463, U. S. Department of Agriculture.*)—Nearly 2,400,000 miles of the two and a half million miles of public roads in the United States are of earth, sand-clay, or gravel, according to recent statistics gathered by the Office of Public Roads and Rural Engineering of the U. S. Department of Agriculture. Roads of these materials are therefore of predominant importance in most communities of the country and probably will remain so for many years. For this reason the Office of Public Roads and Rural Engineering has issued as Department of Agriculture Bulletin No. 463 a comprehensive discussion of the materials, methods of construction, and maintenance for the three types.

Most roads are located originally as earth roads, the bulletin points out. In such location work the fact that the road eventually may develop into an important highway should be kept constantly in mind and routes should be chosen which will not have to be radically changed, perhaps at great expense, at some future time. The tendency in many rural communities to locate all new roads along land lines has been responsible for much waste. The importance of grade, drainage, and width of roads, as well as the materials of which they are built, is emphasized in the publication, and the machinery and tools used in constructing roads of the different materials are described. The necessity for adequate maintenance is brought out, and in this connection directions are given for the making and use of road drags. Typical specifications for the construction of roads from earth, sand-clay, and gravel are included in an appendix.

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DIELECTRIC LOSSES IN INSULATING MATERIALS.*

BY

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INSULATING materials and insulated structures comprise such a tremendous variety in kinds, qualities, and applications that no one test has ever been found which will give even the major part of the information desired in connection with them. Furthermore, in the construction of dynamo electric machinery and apparatus, the value of exact information in regard to insulation has received a rather tardy recognition from designing engineers in general, but, fortunately, the importance of this subject is now more fully recognized. Of the four general classes of materials entering into the construction of dynamo electric machinery and apparatus, insulation is by far the most difficult to evaluate. The other three classes—namely, conducting material, magnetic material, and structural material—have all received more attention in the past, and they are also more readily evaluated with regard to those qualities desirable in the construction of electrical apparatus. The conductivity of copper, the most used conducting material, for example, can be measured with perfect definiteness to a small fraction of one per cent. The mechanical characteristics of this material are some-

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* Presented at a joint meeting of the Electrical Section and the Philadelphia Section, American Institute of Electrical Engineers, held Thursday, March 8, 1917.

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what more difficult of measurement, but, for all practical purposes, can be evaluated to a sufficient degree to allow perfectly definite application to be made. Permeability, hysteresis loss, and eddy current loss in magnetic material can be measured with a fair degree of accuracy, and the mechanical characteristics of such material can be determined with the same degree of precision as those of any other material. The determination of the essential characteristics of structural material used for structural purposes only, in electrical machinery and apparatus, presents a problem common to the determination of such qualities in all structural material. These three classes of material—namely, conducting, magnetic, and structural—are almost exclusively metals, and while there are many unsolved problems in connection with their use, and while a high degree of accuracy in the determination of all of their known qualities is not possible, yet there is far less uncertainty in these determinations than in the measurement of the characteristics of insulating material.

Insulating materials, as is well known, comprise an enormous variety of kinds, compositions, physical characteristics, and qualities. Gases, liquids, and solids are used for different purposes, and the chemical composition runs the whole gamut, from simple oxides, for example, to the most complex hydrocarbons and even more complex mixtures of many substances. In most instances the various characteristics of insulating materials available for a given application are such that the enhancement of any particular quality may require the sacrifice of another desirable quality. For example, increasing the dielectric strength of an insulating varnish usually results in increased brittleness. Increasing the fluidity of transformer oil usually results in decreasing its flashing-point. Increasing the fire-resisting qualities of most insulating structures decreases their mechanical strength and insulating value. It will be seen, therefore, that the study of insulation is an extremely complicated and far-reaching study, beset with many difficulties. Even the mechanical characteristics of insulation are more difficult to evaluate than the same characteristics of the other materials entering into the construction of electrical machinery. Each characteristic of insulating material becomes a special study in itself, and the variation of such a characteristic in different varieties of materials may be enormous. Contrast, for example, the heat resistance of electrical porcelain and of transformer oil.

In the early days of the exploitation of electrical apparatus the magneto was the main dependence of dynamo builders for determining whether or not the insulation was satisfactory. Insulation resistance was sometimes measured with an ordinary galvanometer and a few cells of battery. A little over 25 years ago the idea of making breakdown tests by applying actual potentials to the insulating structures began to be considered by the manufacturers of dynamo electric machinery. A fairly rapid development of this test, now known as the dielectric strength test, resulted, and it is now the main dependence of manufacturers for the evaluation of insulation and insulating structures.

The early use of this same test resulted in very rapid development and betterment in insulating materials and in the insulation of electrical machinery. In this early work tests of a few hundred volts were used for a given service voltage, where now the standard may be ten times as much, with far fewer breakdowns. There was no information available as to what constituted a proper test, and in many cases if apparatus for use on 500- or 1000-volt circuits stood 50 per cent. more it was considered satisfactory. At the period in which your speaker became familiar with this class of work we had no high-tension transmission lines, no voltages available for such testing higher than perhaps two or three thousand, there was no literature whatever available on the subject, and there was no coöperation along these lines between engineers in the various manufacturing companies. It became necessary, therefore, to develop for ourselves the whole art of dielectric testing, including the apparatus necessary for making such tests. From the beginning of a *high-voltage* testing set capable of giving a maximum of 6000 volts by small steps with about one K.V.A. capacity, we now have testing sets capable of giving 500,000 to 1,000,000 volts with a K.V.A. capacity of 500 or more. Ten thousand-, 30,000-, and 50,000-volt testing sets rapidly followed the original 6000-volt set, and with these facilities thousands of tests were made on all kinds of materials and structures. Without going further into the history of this particular development, it is sufficient to say that dielectric strength tests have finally emerged from their chaotic state to a point where they have been standardized by the American Institute of Electrical Engineers and a certain amount of international standardization as to values of test, methods of making them, etc., has been accomplished.

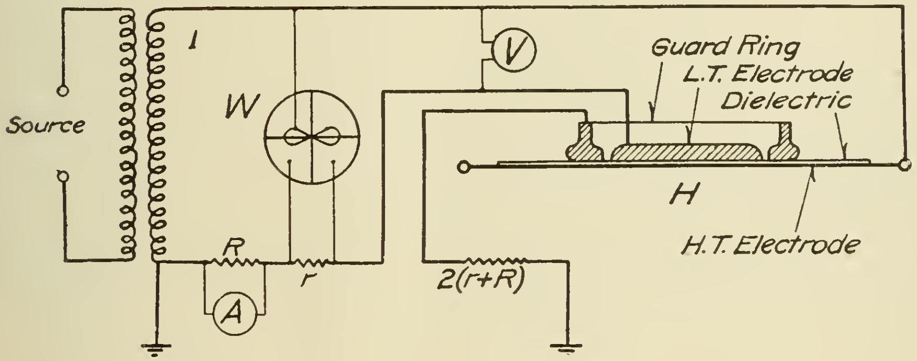
The measurement of insulation resistance has retained a place in insulation testing and is of very considerable value in determining the condition of the material or apparatus with regard to moisture, dirt, curing, etc. The mechanical and other similar characteristics of insulating materials have been studied, but, on account of the enormous variety of materials used referred to, no satisfactory universal test seems possible.

In spite of the standardization of the dielectric strength test for evaluating insulation, and its general adoption and national and even international standardization, it leaves much to be desired. The ultimate value of an insulation or an insulated structure cannot be measured by this method without its destruction. The fact that an armature, for example, stands a test of 10,000 volts gives no indication whatever as to where the structure may break down, and gives no indication of the condition of the insulation except that at the moment of the test it was capable of withstanding this applied electrical pressure. This deficiency in the dielectric strength test has been recognized by workers in this field for many years, and many attempts have been made to use other characteristics of insulation in the determination of its value for the purposes desired. It has long been known that when subjected to an alternating potential, a loss of energy takes place in insulation. While this loss is probably of a much more complicated nature than the hysteresis loss in steel and also much more difficult of measurement, such measurement may be made to serve a useful purpose. Numerous attempts have been made to use this characteristic in the evaluation of insulating materials for general use. A paper on this subject was presented before the annual meeting of the American Institute of Electrical Engineers in 1902 by your speaker, this paper being based on data obtained in several series of tests carried out with the able assistance of Messrs. Miles Walker and Percy H. Thomas. Among the tests described in this paper were several series of loss measurements on materials and on completed apparatus. These losses were obtained by means of a quadrant electrometer adapted for use as a wattmeter. In connection with this paper, another paper by Mr. Miles Walker gave a detailed description of the wattmeter used and the theory involved in its construction and calibration. This paper was followed by a classic paper by Mr. Rayner, of the National Physical Laboratory, before the British Institution of Electrical Engineers, in 1912, Mr. Rayner's measurements also being made with a quadrant electrometer wattmeter. Other workers, notably Messrs. Minton, Shanklin, Thomas, Butman, and others, have given us very valuable contributions to this subject by the use of the cathode ray wattmeter, the electro-dynamometer wattmeter, and the Wien bridge.

All measurements of this class are fraught with many difficulties, regardless of the method and apparatus used. These difficulties may perhaps be appreciated when it is stated that not infrequently measurements must be made of a total value of less than ten watts at voltages of 25,000, 50,000, or even 100,000, and at a power factor sometimes less than five per cent.

During the last five years we have been carrying on practically continuous work on this subject, using a variety of methods, but

FIG. 1.



we have at last adopted the quadrant electrometer wattmeter as the most convenient and satisfactory instrument which we have been able to devise up to date. An instrument of this kind has been constructed which has given very satisfactory results, and upwards of 1000 curves involving variation in voltage, variation in temperature, variation in treatment of materials, etc., have been taken during the last year or two. A considerable variety of insulating materials has been studied in a preliminary way, and measurements have also been made on completed apparatus, such as transformers, generators, condenser bushings, etc.

It is my purpose to give you more or less in detail the construction and calibration of the instruments used, together with some of the characteristic results which have been obtained by their use, in order that other workers may benefit by our experience and go forward with this work.

For these measurements it is necessary to have, in addition to the wattmeter, suitable means of measuring voltages in the testing circuit up to the maximum voltage to be used on the test sample, and also means of measuring the current in this high-tension circuit. The following description, therefore, applies to the various instruments involved.

For this particular work an electrostatic voltmeter designed by Prof. H. B. Smith, of the Worcester Polytechnic Institute, was used. An electrostatic ammeter was adapted from a Kelvin multicellular static voltmeter. In the testing of sheet material it was also necessary to devise suitable electrodes for holding the specimens of sheet insulation so that a uniform field would be produced in that part under measurement. The majority of the tests have been made with materials under oil, as we were primarily interested in the use of these materials under oil, particularly in connection with their application to high-voltage transformers. In many cases measurement in air is difficult, if not impossible, on account of the formation of corona at the higher voltages, which very largely vitiates the results.

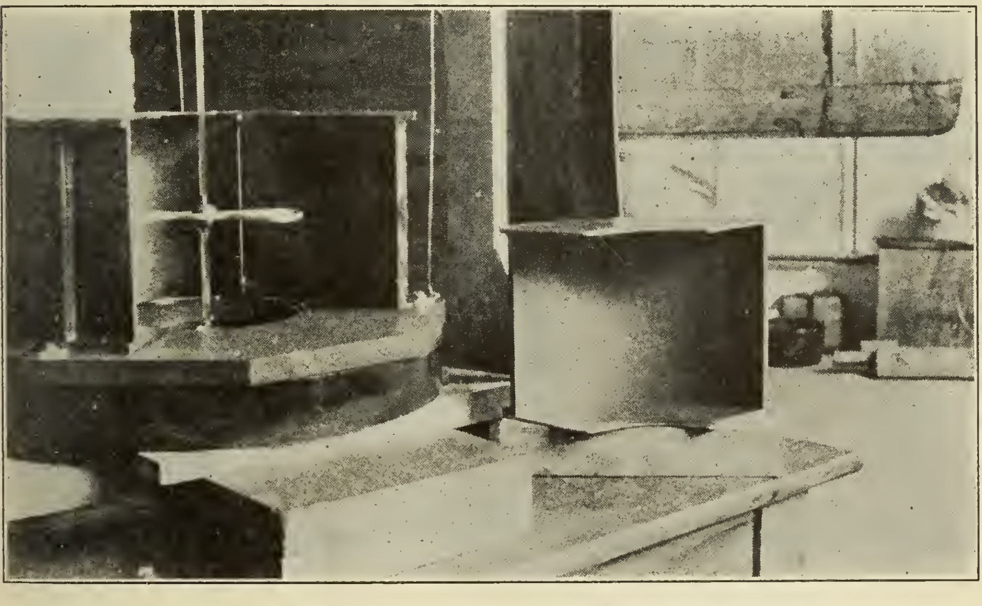
Fig. 1 gives the diagram of connections of the apparatus as used for these tests—*T* being the testing transformer; *A* the Kelvin multicellular voltmeter used as an ammeter, with its resistance, *R; W* the wattmeter, with its resistance, *r; V* the static voltmeter; and *H* the sample holder.

WATTMETER.

The wattmeter is a Kelvin quadrant electrometer adapted for use as a wattmeter, and is simply a refinement and enlargement of the instrument used 15 years ago for the same purpose. The cylindrical parts of the quadrants are of cast iron cast in one piece and turned to 16 inches internal diameter and then cut into four pieces. These quadrants are seven and one-half inches high, and the top and bottom parts are made of one-eighth-inch brass plate. The hole at the top through which the needle suspension passes is seven inches in diameter. All corners are very carefully rounded so as to reduce any tendency for brush discharge. The quadrants are mounted so that the distance between them may be varied from one-quarter inch to thirteen-sixteenths inch. With one-quarter-inch setting it was found entirely feasible to use a voltage of 10,000 between the wattmeter quadrants, which was considerably higher than was found necessary in the testing of specimens of insulation. The base is supported on specially-treated slate, with micarta washers for spacers between the slate and the quadrants. The slate was thoroughly vacuum dried and then given six coats of baked varnish to prevent moisture absorption. The slate rests on a 2-inch pine base, which raises the quadrants sufficiently so that the high-tension lead may be brought in at the bottom of the containing case.

The needle is made of 1/32-inch sheet aluminum, surrounded on the edge by one-quarter-inch aluminum rod to prevent corona disturbances. It is weighted at the centre to hold it in the centre position against the electrostatic forces which tend to pull it aside when a high potential is applied. With this construction, 70,000 volts may be applied between the needle and quadrants without pulling the needle aside from the centre position. A glass tube serves as an axis for the needle, and on this tube is mounted the mirror used for observing deflection.

FIG. 2.

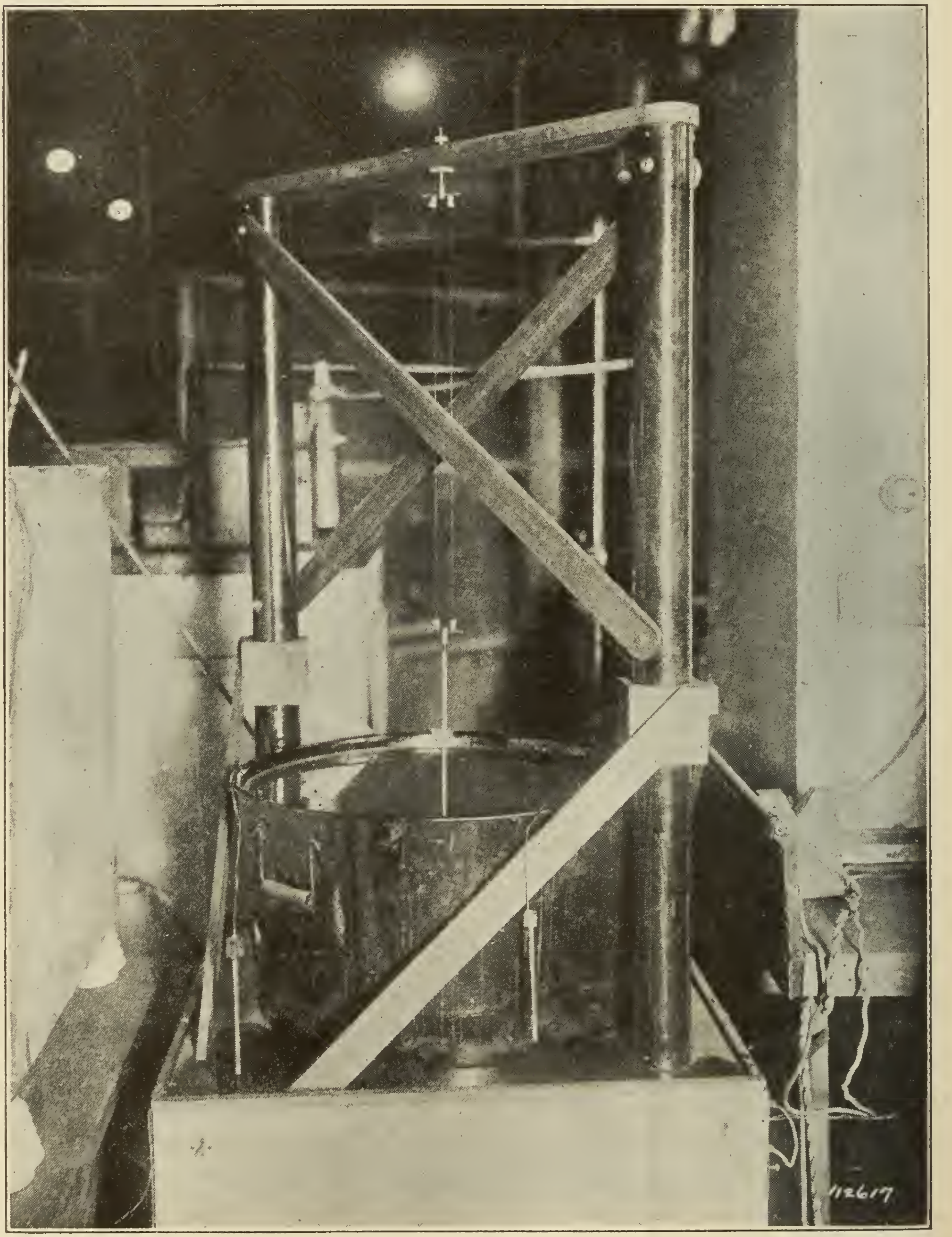


Wattmeter with one quadrant removed, showing interior.

The suspension is bifilar in type, consisting of two 0.01-inch diameter annealed phosphor bronze wires two feet long and one inch apart. This suspension is hung from a solid framework constructed of micarta tubes and treated maple. The suspension has been quite satisfactory, holding its zero position very well.

The whole instrument, excepting the suspension, is immersed in a tub of "HF" transformer oil. This serves to insulate the

Fig. 3.

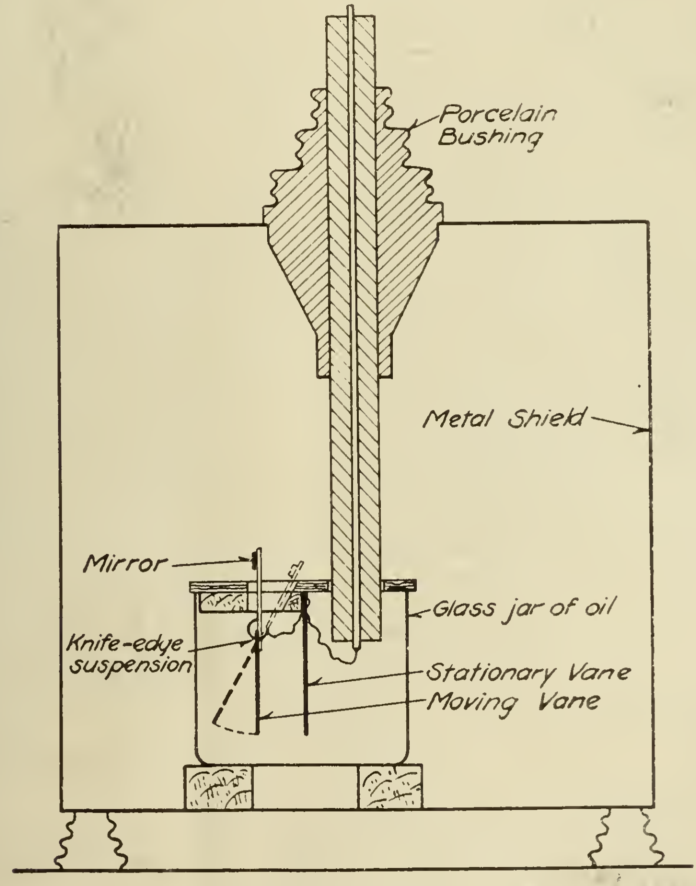


Wattmeter assembled, showing oil container, needle support, and bifilar suspension.

various parts as well as to damp the motion of the needle. The containing tub is made from an ordinary fibre wash-tub thoroughly dried and varnished. The instrument is placed on a rigid table of heavy maple thoroughly treated to prevent the absorption of moisture. The whole is completely surrounded by a shield of galvanized sheet iron to prevent errors which might otherwise be caused by stray electrostatic fields.

The high-tension lead is brought through the casing at the base of the instrument through a heavy porcelain bushing and passes to a heavy stud projecting through the bottom of the tub.

FIG. 4.

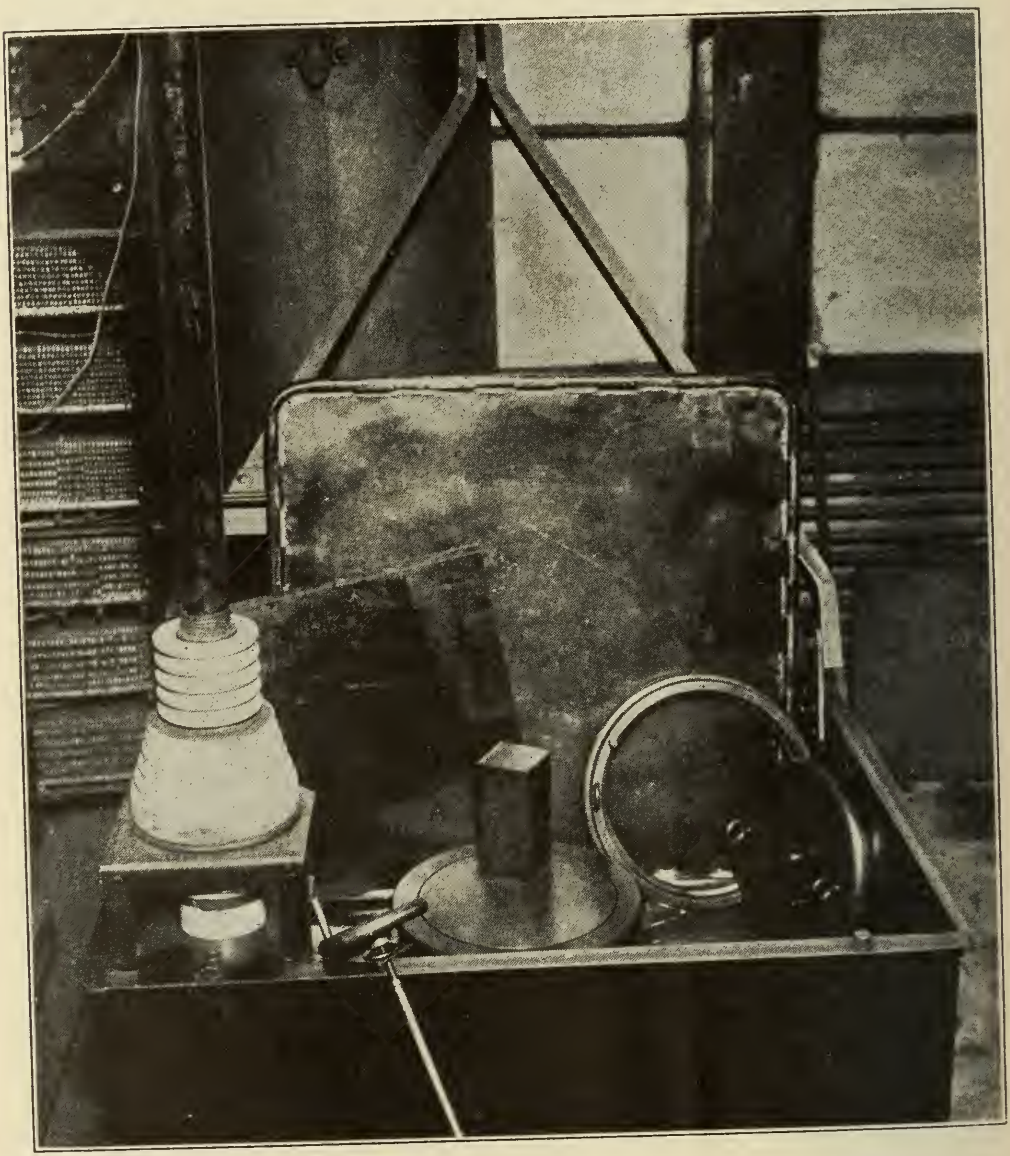


Electrostatic voltmeter.

On top of the stud is a mercury cup used for making contact with the needle. Metal guard disks are used on the stud above and below the bottom of the containing tub to eliminate corona at these points. The low-tension leads from the quadrants are brought out of the oil near the edges of the tub and pass through the side of the upper shield through suitable porcelain bushings. The instrument is levelled by suitable levelling screws applied to the supporting table.

The wattmeter resistance consists of two 50,000-ohm Weston resistances, each having a current capacity of 0.05 ampères. For larger currents a ribbon resistance specially manufactured by the Paul Instrument Company is used. Very careful check tests indicate that these resistances are practically non-inductive and have negligible capacity.

FIG. 5.

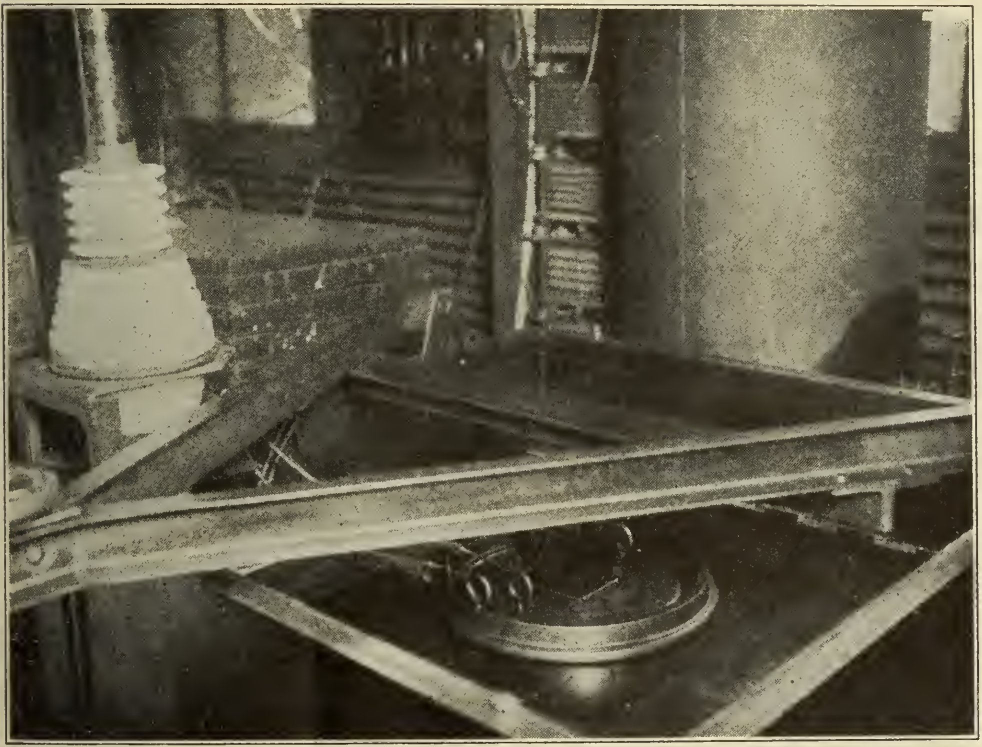


Testing electrodes shown in containing tank with outlet terminal.

VOLTMETER.

The voltmeter used is shown diagrammatically in Fig. 4, and consists of a stationary vane, three inches by five inches, made of brass, with a moving vane of aluminum, three inches by three inches. The moving element is supported on knife-edges and carries a mirror. The vanes are supported by blocks of treated maple, which are held in a glass jar of "HF" transformer oil. The whole is placed in a metal box to protect the meter from stray electrostatic fields. This box also serves as the low-tension (or grounded) terminal. The high-tension lead is brought in at the top through a suitable high-voltage porcelain bushing which extends down into the oil, leaving no live parts exposed inside the case. The voltmeter box is supported on porcelain insulators, this arrangement allowing the metal box to be connected to the low-tension side of the load under test, which may be as much as 2000 volts above ground potential. Both the voltmeter and wattmeter are read by means of telescopes and illuminated scales six feet distant from the mirrors. The wattmeter scale is horizontal, 30 inches long, and the voltmeter scale, vertical, 50 inches long.

FIG. 6.



Assembled testing electrodes in tank, showing arrangement for securing pressure on test sample.

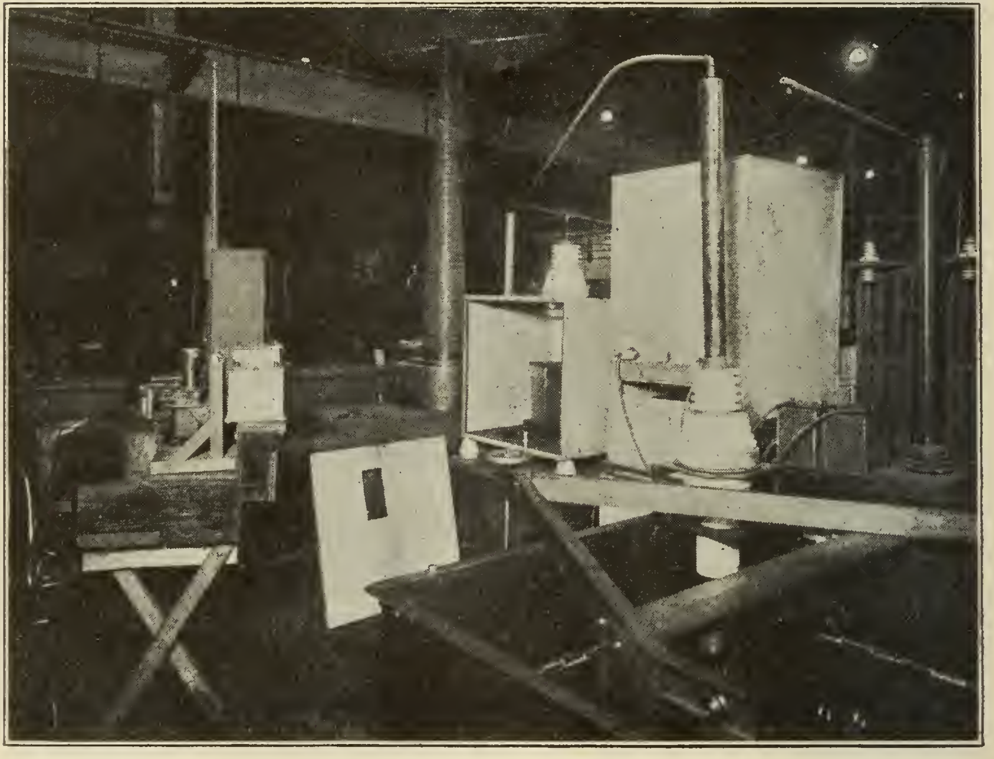
AMMETER.

The ammeter, as before indicated, consists of a multicellular electrostatic voltmeter with an adjustable shunt so that different values of resistance can readily be inserted without opening the circuit.

ELECTRODES AND OIL TANKS.

The construction of the electrodes was shown diagrammatically in Fig. 1. As will be seen in this sketch, the lower electrode consists of a thin sheet of steel with brass tubing completely surrounding this sheet to form a round edge, this being supported on suitable insulators in the containing tank and serving as the high potential or ungrounded electrode. The low potential or grounded electrode consists of a heavy circular casting surrounded by a carefully-finished guard ring, this serving to prevent stray fields and to keep the field uniform in that portion of the material under test.

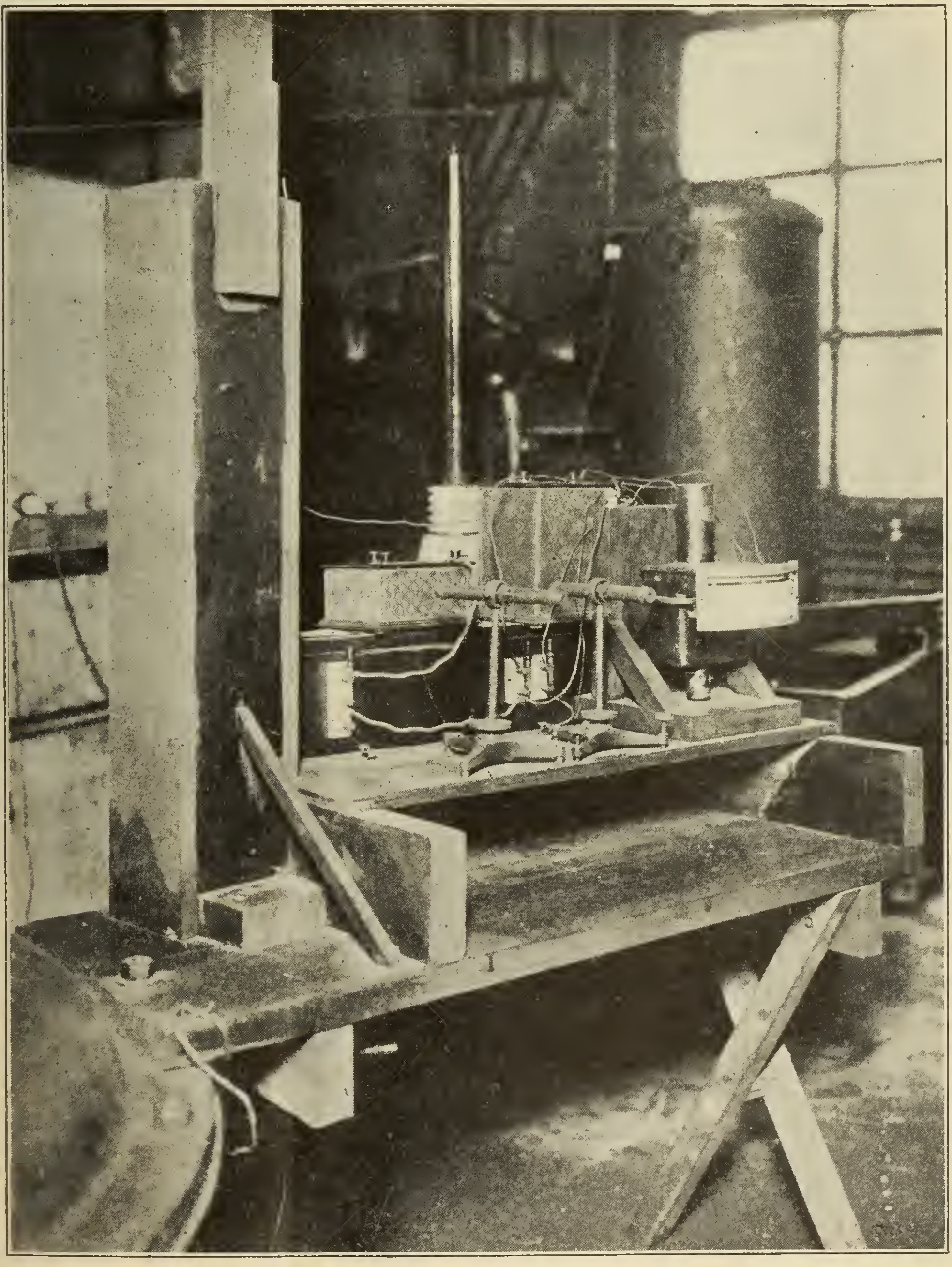
FIG. 7.



General view of testing apparatus.

The diameter of the low-tension electrode is 14.05 inches and the inside diameter of the guard ring 14.3 inches, leaving a space of ⅛ inch between the electrode and guard ring. The contact surface of the low-tension electrode is 1000 square centimetres and the contact surface of the guard ring approximately 500

FIG. 8.



Observation desk, showing telescopes and static ammeter, with oil tank, test sample tank, and instruments in background.

square centimetres. A resistance is inserted in the connection of the guard ring to ground such that the potentials of the ring and the low-tension electrode are the same, and therefore corona is practically eliminated from the part of the sample under measurement.

The specimen tank has a capacity sufficient to contain approximately 125 gallons of oil, and is connected to a storage tank, with the necessary pump to transfer the oil to or from the specimen tank. Approximately ten minutes are required to pump the oil from one tank to the other. In the storage tank are placed electric heaters with sufficient capacity for heating the oil to any desired temperature up to 130° C. Provision was also made for circulating the oil from the storage tank to the specimen tank and back and for keeping it at any desired level in the specimen tank. By means of the heaters and this arrangement for circulation the oil in the specimen tank can be adjusted to and held at any desired temperature during the test.

By means of a lever arm and weights, provision is made for applying any desired pressure up to ten pounds per square inch (0.7 Kg. per sq. cm.) on the specimen under test It was found that this pressure, applied before the admission of the oil to the specimen tank, satisfactorily kept the oil from the specimen under test. As most of the tests desired were on oil-soaked material, a certain amount of admission of oil, however, was not considered detrimental.

THEORY OF WATTMETER.

A. Fundamental Equation.

The fundamental equation for the quadrant electrometer, as stated and proved by Clerk Maxwell,[1] is:

$$T = K_1(AB)\left(C - \frac{A+B}{2}\right)$$

where

T = Torque on needle.
K_1 = Constant of the instrument.
A, B = Absolute potentials of the two pairs of quadrants.
C = Absolute potential of the needle.

The deflection of the instrument is seen to be proportional to the product of two voltages: the voltage between the pairs of quadrants, and the voltage between the needle and the mid-potential of the quadrants. When used on alternating current the phase relations of these two voltages is also a factor in determining the deflection, since two voltages which are 90 degrees apart can produce no torque in an electrostatic instrument of this kind.

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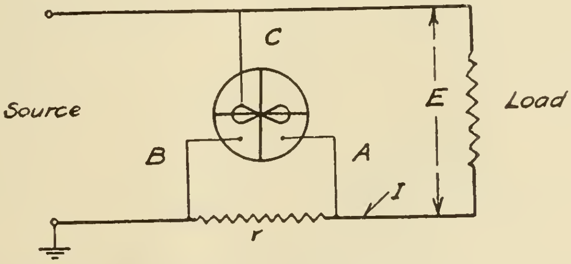
[1] Treatise on Electricity and Magnetism, vol. i, sec. 219.

B. Connection of Electrometer as Wattmeter.

Fig. 9 gives the diagram of the connections necessary for the use of an electrometer as a wattmeter, as used in these experiments. *A, B, C* are the potentials of the respective parts of the electrometer shown in the figure. E is the voltage across the load, and I the current. r is a non-inductive resistance, called the wattmeter resistance or potential divider, used to produce a difference of potential across the quadrants which is proportional to and in phase with the current I.

FIG. 9.



"C." Proof that Wattmeter Indicates Watts (100 per cent. P. F.).

Assuming the deflection (d) is proportional to the torque on the needle, which is true for the small deflections used, we have, from Maxwell's equation:

$$d = K_2(A - B)\left(C - \frac{A+B}{2}\right) \qquad (1)$$

Here K_2 is a new constant.

If the load is a resistance only, the drop across the quadrants ($Ir = A-B$) is in phase with E, the voltage across the load. Now as B is earthed, its potential is zero; A, therefore, has a potential of Ir volts, and C of $(Ir + E)$ volts. The above formula becomes:

$$d = K_2(Ir)\left(Ir + E - \frac{Ir}{2}\right) \qquad (2)$$

$$= K_2 r\left(EI + \frac{I^2 r}{2}\right) \qquad (3)$$

Thus it is seen that the deflection is proportional to the sum of the watts consumed by the load plus half the I^2r loss of the wattmeter resistance. Should B be at some potential (say x) above earth, and not zero, as in the figure, the discussion would not be changed, for then we would have:

$$d = K_2(Ir + x - x)\left(E + Ir + x - \frac{Ir + 2x}{2}\right) \ldots\ldots\ldots\ldots\ldots (4)$$

which reduces to the same as (3):

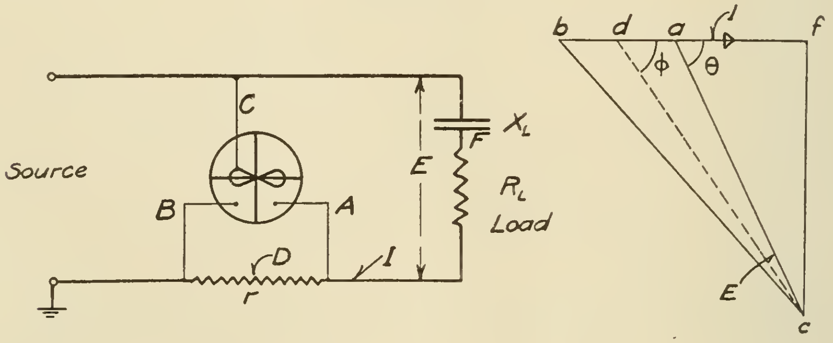
$$d = K_2 r\left(EI + \frac{I^2 r}{2}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

The foregoing discussion holds for loads having a power factor of unity. A proof for any power factor is as follows:

D. Proof of Wattmeter On Any Power Factor.

Fig. 10 gives a sketch of the circuit ordinarily met with in insulation testing, together with the vector diagram. R_1 and X_1 represent the theoretical resistance and capacity of the insulation load, which has a power factor of cos θ. E is the potential drop across the load, and I the current. r is the wattmeter resistance, described above. The other letters, *A, B, C, D,* and *F,* refer to the potentials of those parts of the circuit which they represent, and correspond to the small letters *a, b, c, d,* and *f* in the vector diagram. *ac* is the voltage across the load, *bc* the voltage of the source, *ba* the voltage across quadrants, and *cd* the voltage from the needle to the middle point of the quadrant voltage. From Maxwell's fundamental equation, the deflection is proportional to the product of the voltage between quadrants (*ab*) and the voltage from the needle to the middle point of the quadrants (*cd*), or

FIG. 10.



$$\text{Deflection} = K_2 \times \overline{ab} \times \overline{cd} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

$\overline{ab}$ and $\overline{cd}$ being vector quantities.

From the vector diagram in Fig. 10 this becomes, in scalar quantities:

$$\begin{aligned}\text{Deflection} &= K_2 \times ab \times cd \cos \phi \\ &= K_2 \times ab \times (ac \cos \theta + da) \\ &= K_2 Ir\left(E \cos \theta + \frac{Ir}{2}\right) \\ &= K_2 r\left(EI \cos \theta + \frac{I^2 r}{2}\right) \ldots\ldots\ldots\ldots\ldots\ldots (7)\end{aligned}$$

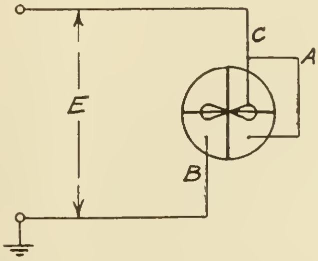
Thus it is seen that the wattmeter records watts for a condenser load (such as is common when insulating materials are tested). The proof for a reactance load is similar and will not be given here.

CALIBRATION OF INSTRUMENTS.

Wattmeter.

The constant of the electrometer wattmeter has been determined in several ways, each method checking within two or three per cent. The usual method has been to connect the instrument as a voltmeter, as shown in Fig. 11. Applying the fundamental equation, the constant is found from the formula

FIG. 11.



$$K_2 = \frac{2d}{E^2}$$

where

K_2 = constant.
d = deflection.
E = voltage.

The instrument has been checked frequently and the variation of the constant found to be very small, the maximum variation during the considerably more than twelve months' use being not over two and one-half to three per cent. The constant for the instrument is practically uniform over the entire scale length, the following data being a fair representative of the usual test:

Volts	Deflection, cm.	K.
1520	.46	3.98×10^{-7}
3140	2.01	4.07×10^{-7}
4790	4.70	4.10×10^{-7}
6440	8.40	4.05×10^{-7}
8120	13.32	4.04×10^{-7}
9720	19.05	4.03×10^{-7}
Average		4.04×10^{-7}

The most reliable check on the wattmeter constant is made by measuring actual energy of known amount. The following table gives a summary of some tests made with known load:

Frequency	Calculated from load constants		Calculated from Wattmeter deflection. K.
	Total watts	P. F. of Load	
25	126.8	1.00	4.03×10^{-7}
25	88.2	.31	4.13×10^{-7}
25	140.8	.15	4.13×10^{-7}
60	124.	1.00	4.00×10^{-7}
60	132.2	.14	4.12×10^{-7}
60	126.	.065	4.13×10^{-7}
25	Calibration as a voltmeter		4.13×10^{-7}
60	Calibration as a voltmeter		4.12×10^{-7}

From the above tests it is seen that the wattmeter gives readings consistent within three per cent. on 60 and 25 cycles and on power factors from 6½ to 100 per cent. Lack of suitable condensers and resistances made it impossible to make any check tests with known loads below 6½ per cent. power factor. With the above tests checking so closely, however, it is safe to assume that the wattmeter is accurate on lower power factors within the limit of possible errors of reading the instrument and measuring the current, voltage, etc.

It should be noted here that the possible error is much greater with a low power factor, due to the fact that the watts registered by the meter is the sum of the loss in the load plus half the loss in the wattmeter resistance. So far a power factor of 1½ per cent. is the lowest that has been registered with this arrangement.

Possible Wattmeter Errors.

A very careful study was made of possible errors in the wattmeter, and it is believed that such errors have been very largely eliminated. It was found that the constant of the wattmeter was more uniform with the quadrants set at the smaller distance of one-quarter inch from each other than for larger distances, and this setting was therefore used for all the measurements. It was found that the wattmeter would have a small deflection with the quadrants short-circuited and grounded and with a high voltage on the needle. This was due to dissymmetry in the location of the quadrants, and was corrected by adjusting the quadrants until zero deflection was obtained with high voltage on the needle and the quadrants connected together and to ground.

With voltages in excess of 70,000 the needle becomes unsteady, due to the electrostatic forces acting on it. Measurements were therefore confined to voltages below this value.

Mr. Rayner has noted an error due to the charging current to the needle. Most careful tests in the case of the instrument in question indicated that the amount of this error was negligible. As will be seen from the diagram of connections, any loss in the voltmeter will be measured by the wattmeter. Even at the highest voltages used it was found that these losses were so small that no perceptible difference could be detected in the readings of the wattmeter with the voltmeter connected or disconnected. The insulation resistance of the base of the wattmeter was considered a possible source of error, but measurements indicated this insulation resistance to be of such high value as to make any such error negligible.

The question has arisen as to whether there might be an error due to the inductance or capacity of the wattmeter resistance. Weston precision resistances are used, and tests were made in which no inductance or capacity could be detected. The voltage across these resistances is such that the effect of corona, or of leakage due to distributed capacity, is practically *nil*. The actual error due to a one-half per cent. capacitance in the wattmeter resistance can be shown to cause an error of but three per cent. in the wattmeter reading on an average sample of insulating material.

Some question may arise as to the accuracy of the meter on currents and voltages which have a wave shape other than sinusoidal. While care was used to supply as nearly as possible a sine-wave source of potential to the testing transformer, experiments show that in many cases the shape of the current wave through the dielectric is distorted in spite of any precautions that may be taken. It should be noted here that the voltmeter and ammeter read the true effective values of volts and current regardless of wave shape. The mathematical proof of the wattmeter for wave shapes other than sinusoidal is more difficult, but such proof has been made. However, the consistency with which the measurements can be made of the energy losses in known loads having various power factors and producing distorted wave shapes is sufficient proof in itself that the wattmeter reads the true watts with wave shapes other than sinusoidal.

Calibration of Voltmeter.

The static repulsion type voltmeter, when first set up, was used with an equally divided scale. But, as the deflections are very nearly proportional to the square of the voltage, it has been found convenient to make a direct-reading scale. The meter holds its calibration extremely well, and there is apparently nothing to get out of order.

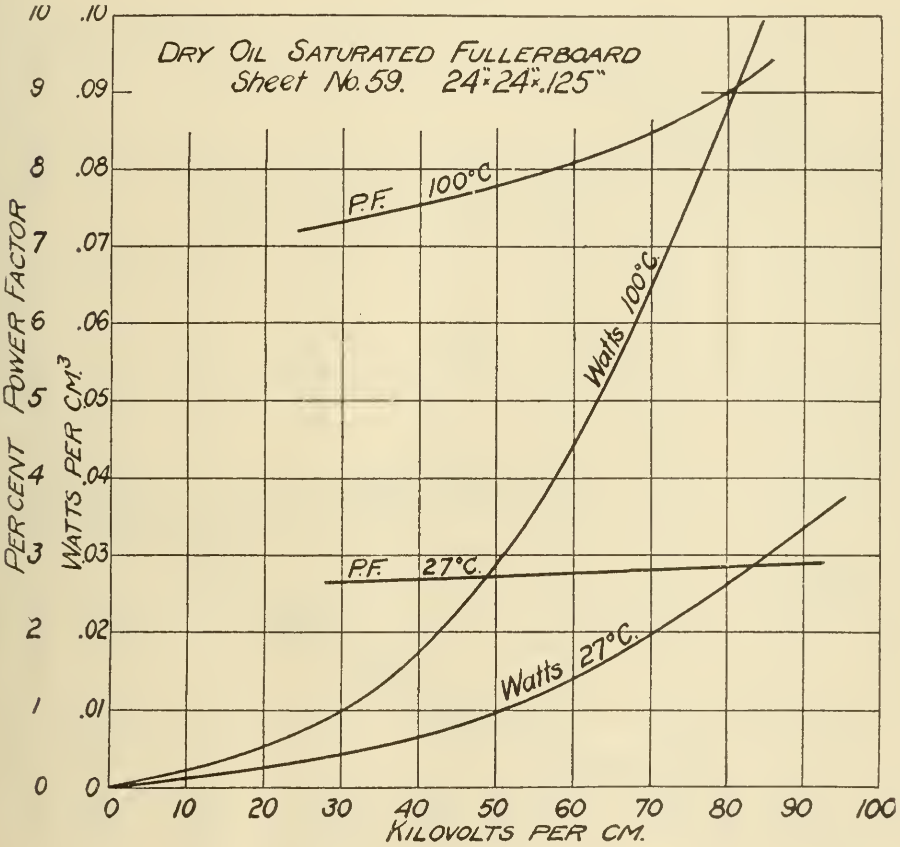
Calibrations have been made on 25 and 60 cycles, with an instrument transformer on the high-tension side of the testing transformer, and also by means of a voltmeter on the primary side of the testing transformer. In all tests the results agreed within a fraction of one per cent., and it has been thought unnecessary to calibrate further, except to check a few points on the scale occasionally. The meter has a good readable scale, from two to 57 kilovolts. The closeness to which it may be read is given in the table:

Scale reading	Smallest division which may be estimated
2 KV.	.1 KV.
5 KV.	.1 KV.
10 KV.	.05 KV.
25 KV.	.02 KV.
50 KV.	.01 KV.

RESULTS OF TESTS.

Data for many hundred watt loss curves have been taken with the apparatus described, an average of five points being taken for each curve. While the setting up, calibration, and operation of these devices require extreme care, when once adjusted measurements can be made quite rapidly and satisfactorily and, it is believed, with a degree of accuracy sufficient for all practical purposes. It was found comparatively easy for one operator to make all calculations and plot logarithmic curves of watt loss, power factor, and current against voltage for any given sample in the time required for another operator to remove the sample from the tank and replace another, which ordinarily occupied about twelve minutes. In adjusting for temperature, considerable time is naturally consumed, and it is interesting to note that the point at which the temperature of a given sample had reached a uniform value throughout for any given temperature was determined by the measurement of insulation resistance. It was considered that the temperature of the sample had reached a constant value when the insulation resistance became constant. The time required varied, of course, with the kind and bulk of the sample under test. Insulation-resistance readings were usually made on samples as well as loss and power factor readings, these insulation-resistance measurements being made with direct-current voltages up to 10,000.

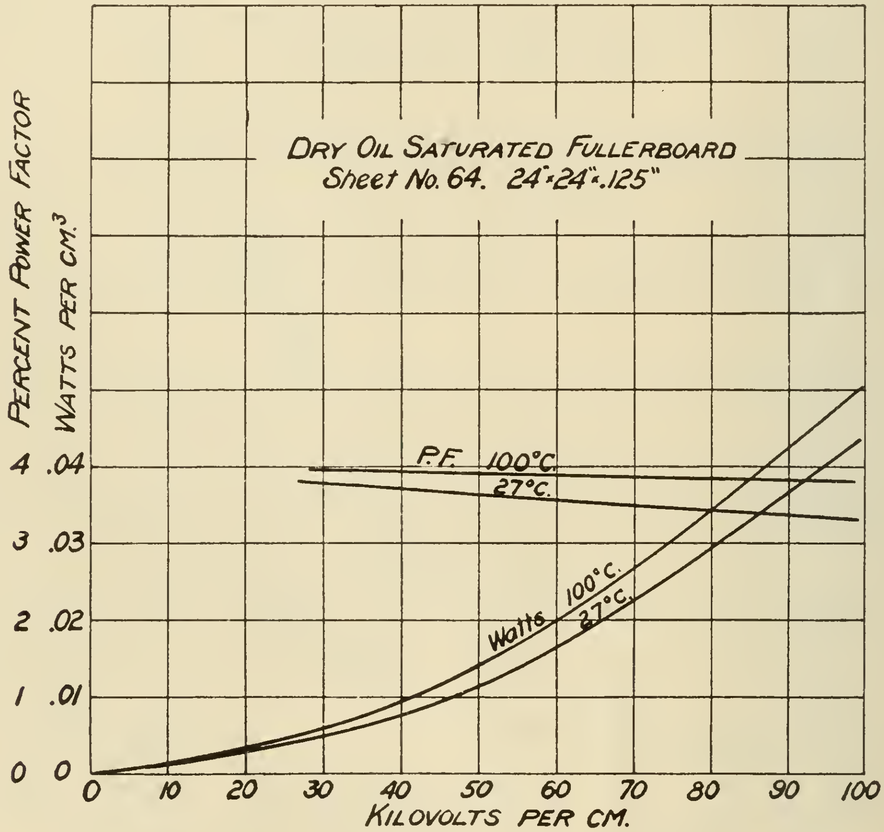
FIG. 12.



This sheet was dried and saturated with oil by the vacuum pressure method. It then stood 10 days in air in the laboratory before being tested in oil

The following curves give a number of specific examples of the results obtained by this investigation. These curves should not, however, be taken as representative of the various classes of materials, due to the fact that in practically all classes investigated different samples of the same material often show as much variation as different kinds of materials, and, as will be shown, the results are profoundly influenced by various kinds of treatment.

FIG. 13.



This sheet was tested in oil immediately after being dried and saturated with oil by the vacuum pressure method.

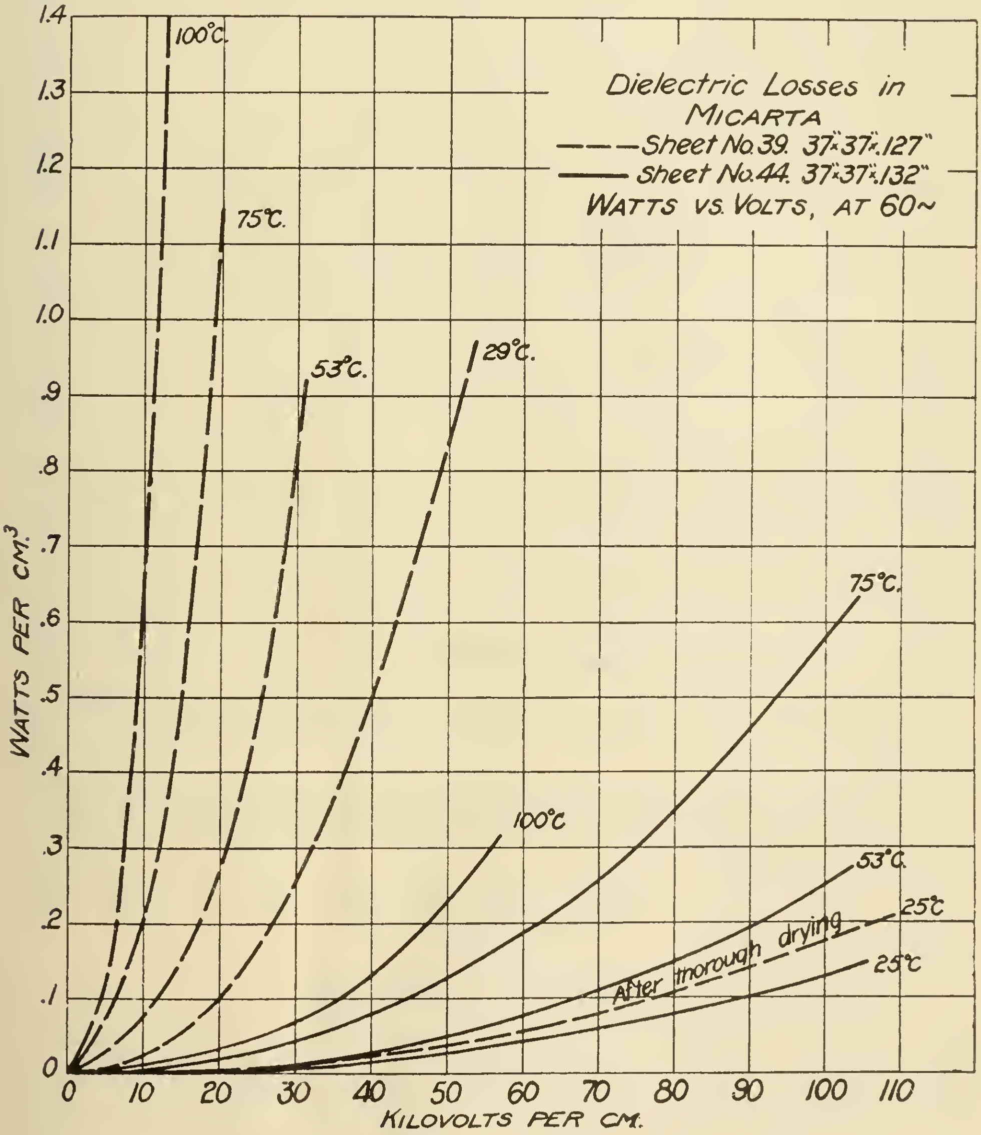
This study has been of very great value in various manufacturing processes in pointing out the kind and duration of treatment necessary to put various materials into the best condition for use, but in order to draw satisfactory conclusions from any sample or set of samples it is necessary to know something of their mode of preparation, previous treatment, etc. In general it may be said that the lower the losses and power factor and the higher the insulation resistance the better the quality of the insulation.

As a rule, low specific inductive capacity is desirable, but not for all uses.

SHEET MATERIAL, SUCH AS FULLER-BOARD, MICARTA, ETC.

One of the most commonly used materials for electrical insulation is known as fuller-board or press-board. This material is very largely used, especially in large, high-voltage transformers,

FIG. 14.

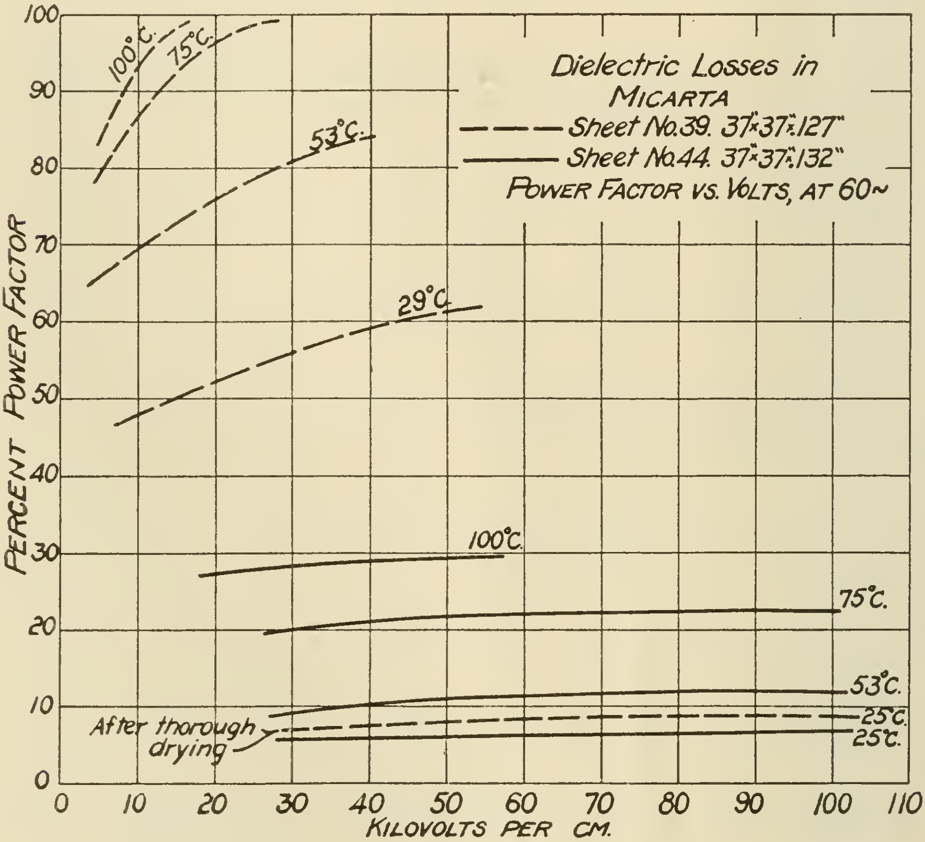


for the main insulation. In some cases this fuller-board is treated with a varnish or a drying oil, and in other cases it is merely thoroughly dried and impregnated with the oil in which the transformer is immersed.

Fig. 12 shows the relation between power factor and kilovolts per centimetre thickness, and also the relation between watts per cubic centimetre and kilovolts per centimetre thickness at two temperatures.

Fig. 13 gives a similar curve for a second sample of the same material, and it will be noted that there is a very wide difference in the values of the watts loss and power factor of the two samples, particularly at a temperature of 100° C. The only known difference between the two samples was that the first sample (Fig. 12) was exposed to ordinary atmospheric influences for a period of ten days after being vacuum dried and oil saturated. Although it is oil-soaked, this sheet had undoubtedly absorbed a small amount of moisture which affected its insulation resistance at high temperatures, as well as its other characteristics. Dielectric tests made on these materials in the ordinary manner would show little or no difference in quality. Even the poorer results are considered

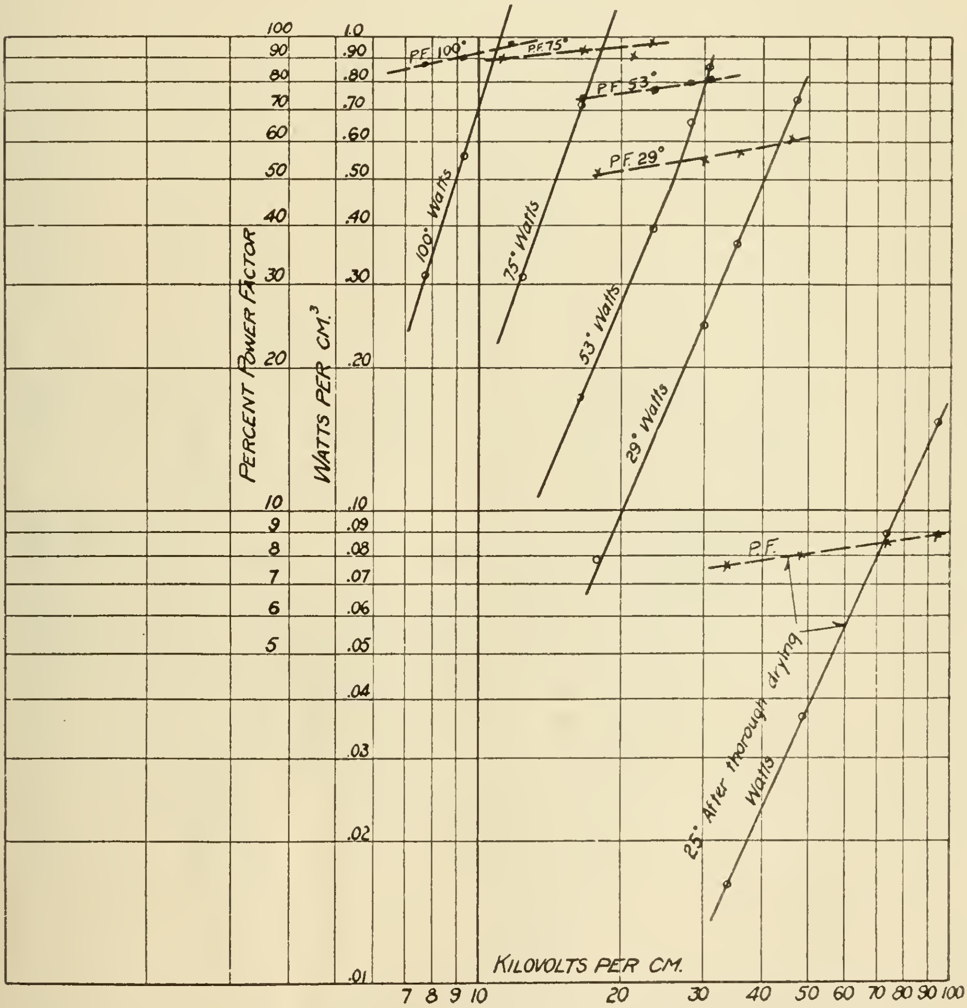
FIG. 15.



very satisfactory, as it will be seen that the losses are extremely small and the power factor relatively low.

Fig. 14 gives the relation of watts per cubic centimetre to kilovolts per centimetre on two samples of micarta sheet which were purposely taken in very different condition as regards their previous preparation. Sheet 39 was only partially processed, and it will be seen that the losses are excessive. The same sheet was again tested, after thoroughly drying, as indicated by the broken curve at the lower part of the figure, and a very decided improvement in the material is shown.

FIG. 16.



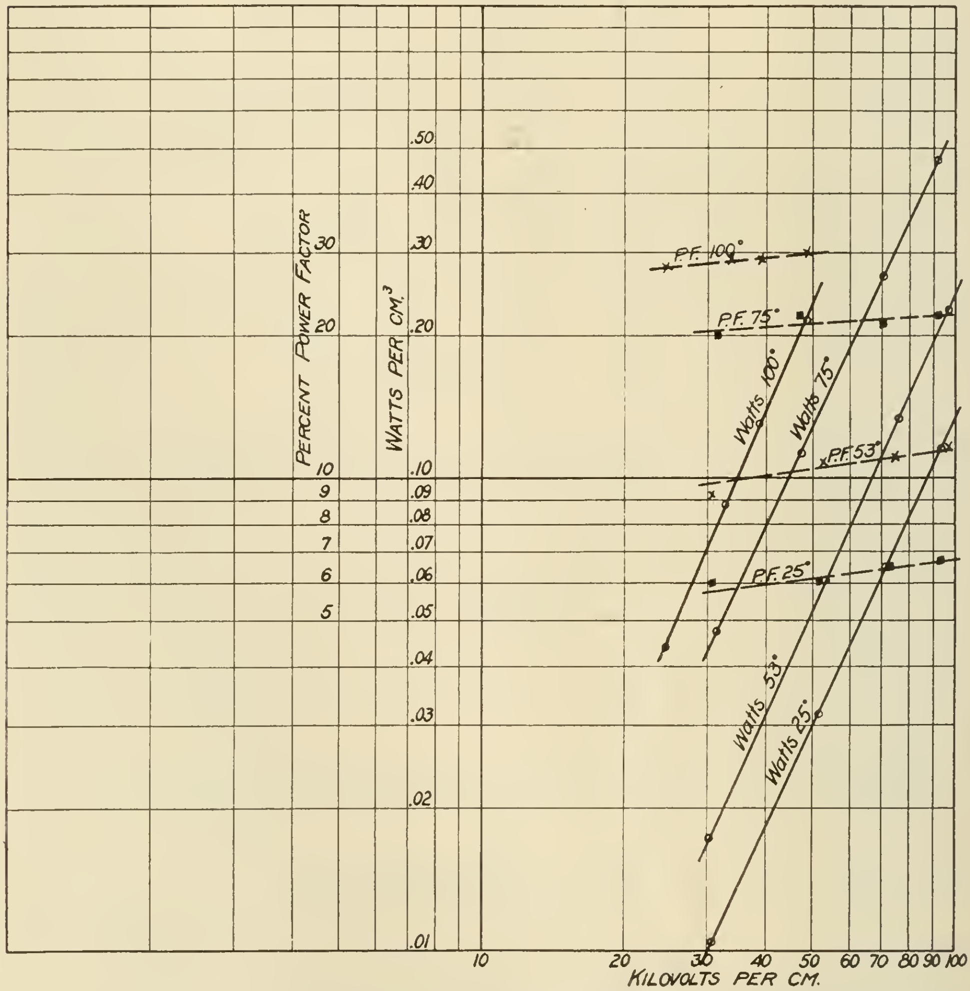
Logarithmic Plot of Dielectric Losses in Micarta Sheet No. 39. Watts and Power Factor vs. Volts, at 60~

Fig. 15 shows the relation between power factor and kilovolts per centimetre for the same samples as shown in Fig. 14.

It will be seen that in the uncured condition the power factor of this material reaches almost 100 per cent. at the higher temperature. The power factor is considered relatively high even for the better samples, and, as has been shown in other tests, this can be greatly reduced by proper processing.

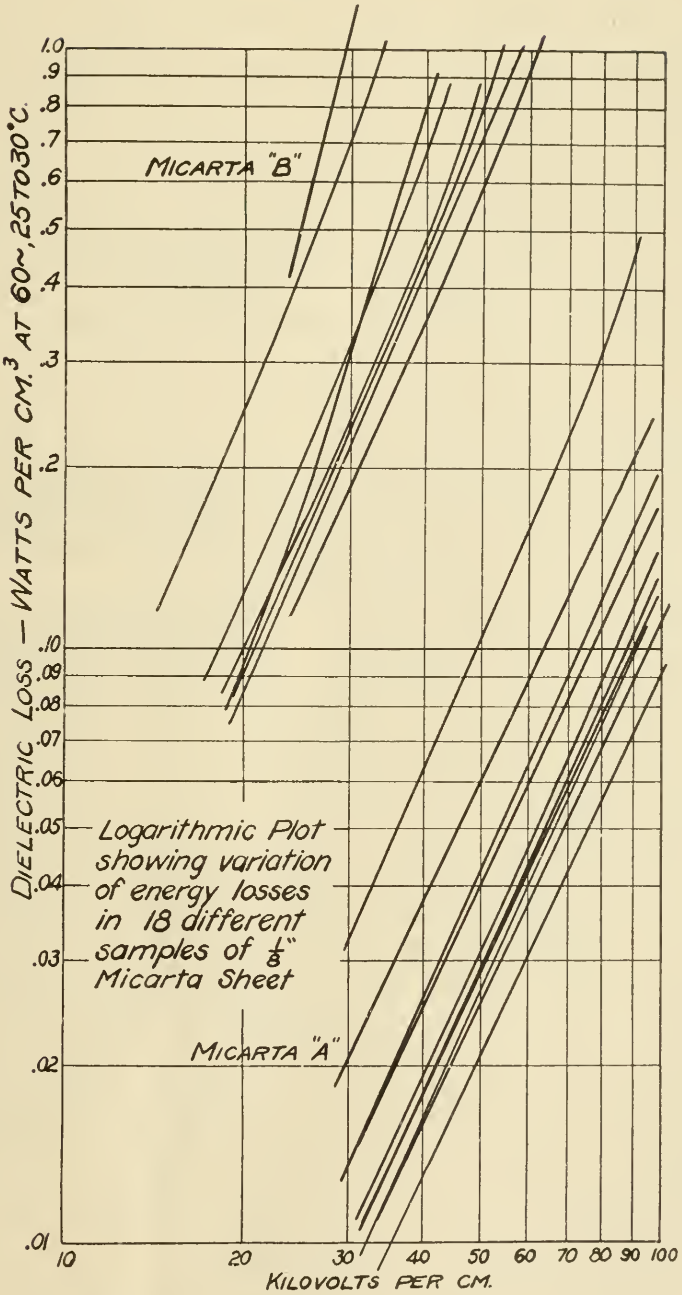
The same data given on Figs. 14 and 15 are repeated on Figs. 16 and 17, plotted to logarithmic scale, and in this case the actual observation points have been included. It will be noted particularly on these logarithmic scales that the slope of the watt voltage curve increases with temperature. The straight part of this curve may be expressed by the formula

Fig. 17.



Logarithmic Plot of Dielectric Losses in Micarta. Sheet No. 44. Watts and Power Factor vs. Volts, at 60~

FIG. 18.



$$W = KE^n$$

where

W = Watts
E = Kilovolts
K = A constant for a given temperature and frequency
n = An exponent indicating the slope of the curve on the logarithmic plot

The point where the watt loss curve departs from the straight line (Fig. 16—53° test) indicates some change in the material which foretells breakdown if the stress is continued at this value. The voltage was applied in this case for only a few seconds, and the wattmeter deflection showed that the actual watt loss was increasing rapidly due to this application. The subsequent measurements on this sheet at higher temperatures were made at lower voltages. This critical point is most readily determined by plotting to logarithmic coördinates.

FIG. 19.

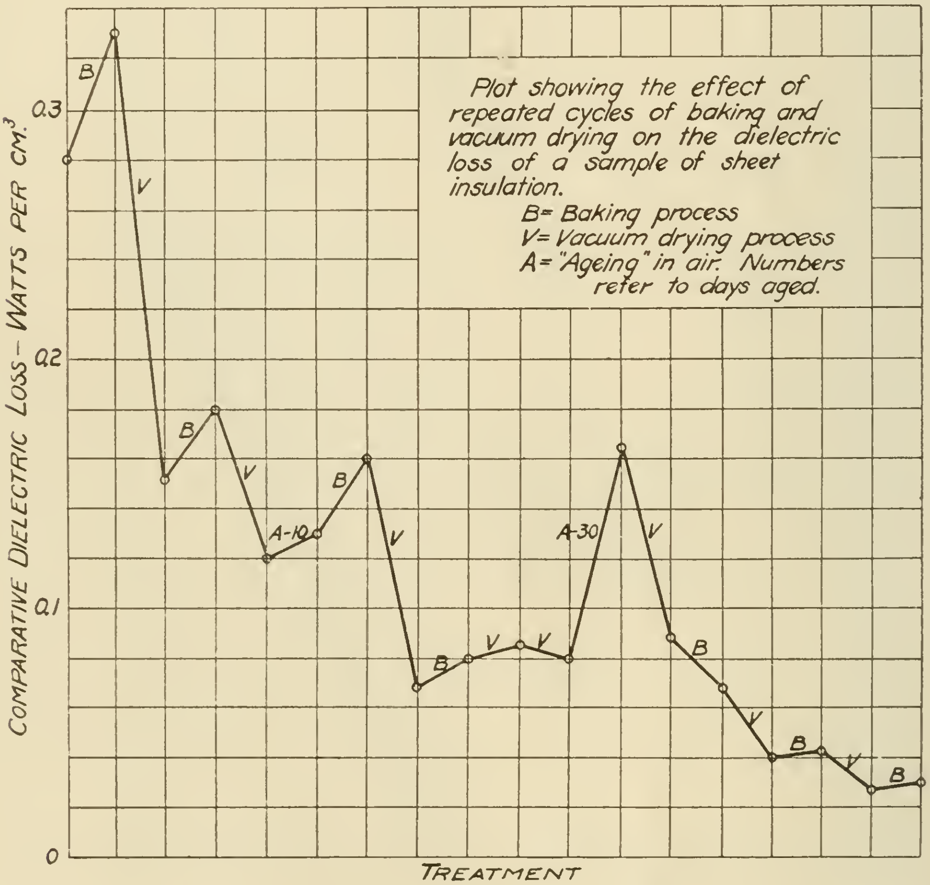
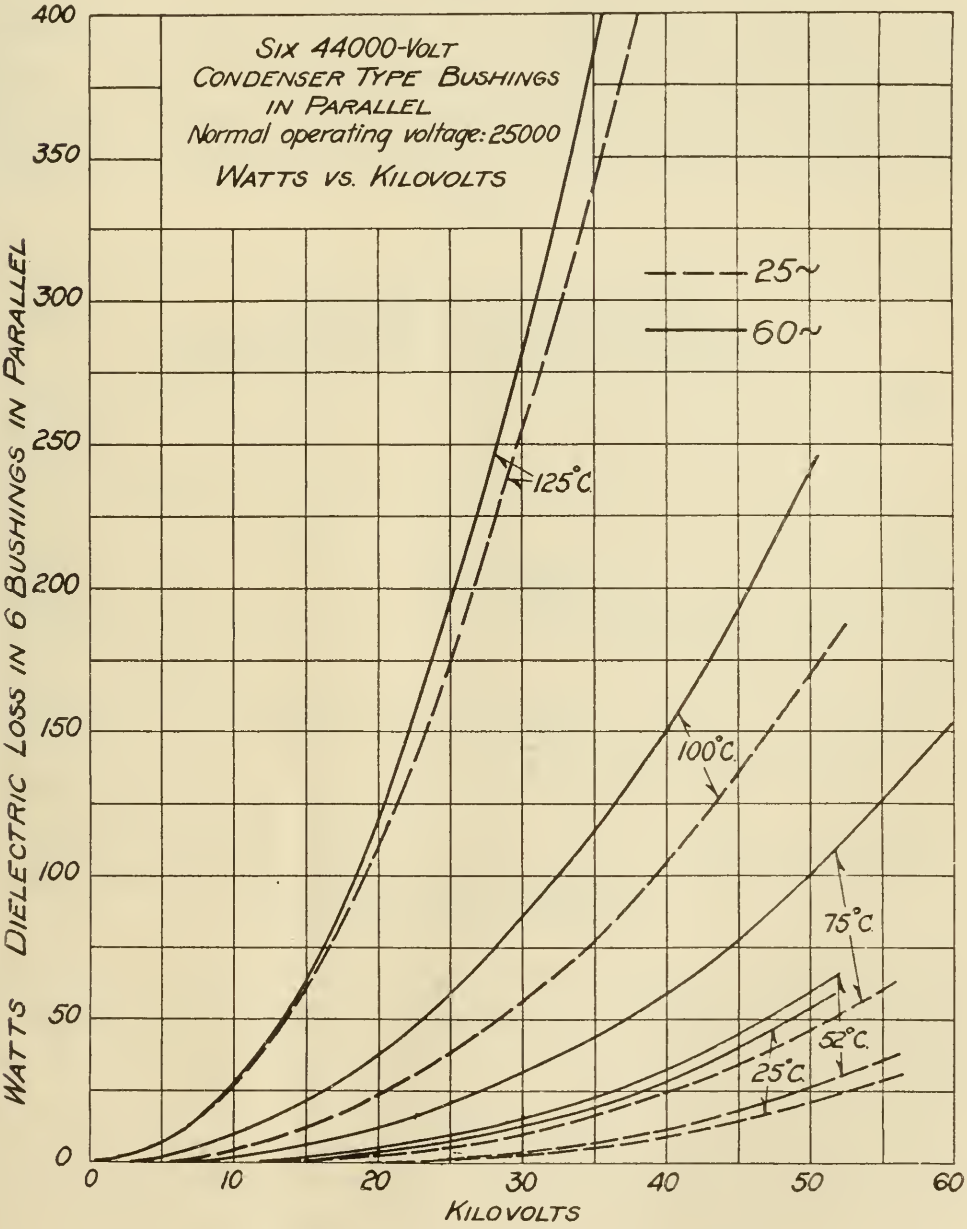


Fig. 18 gives the results of tests on a number of samples of micarta plotted to logarithmic scale. When plotted to this scale, the upward bend at the upper end of some of the curves indicates in those cases that the material was approaching very closely to its breakdown value.

Fig. 19 is extremely interesting as showing the variation in dielectric loss of sheet insulation when subjected to various treatments. In a general way this plot can be taken as characteristic, particularly for sheet insulation treated or filled with varnish, and shows that such losses can be very greatly decreased by proper treatment. While insulation resistance measurements were not

FIG. 20.

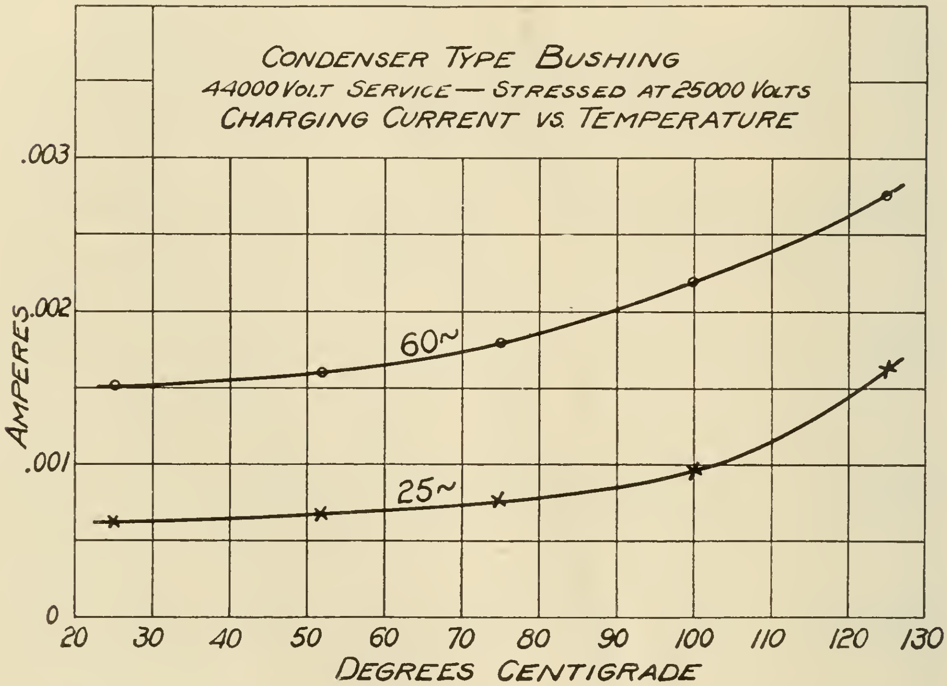


taken, it is probable that the effect of the treatment has been much greater numerically on the insulation resistance than it has been on the dielectric loss, particularly at high temperatures. Attention should be called to the fact, however, that at ordinary temperatures the dielectric loss is a far better indication of the quality of the material than the insulation resistance.

CONDENSER BUSHINGS.

The condenser bushing consists, essentially, of concentric tubes of micarta, with intervening tubes of conducting material, the length, diameter, and thickness of the tubes being so adjusted that the electrostatic capacity of the successive layers is equal. On account of the very low dielectric losses and power factors of this condenser bushing at normal operating voltage, test was made

FIG. 21.

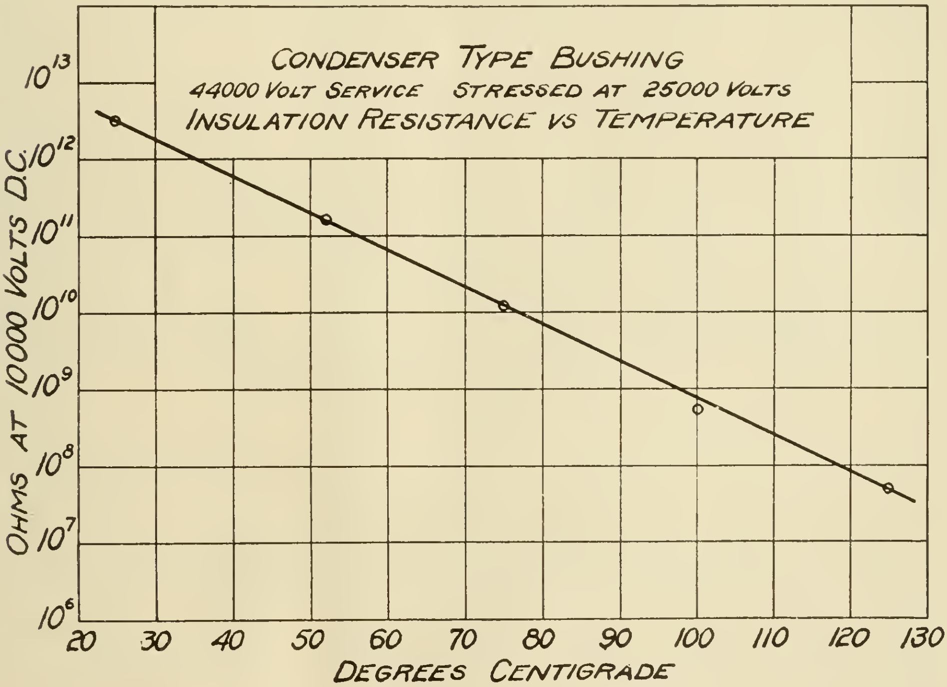


by measuring six bushings in parallel to secure more measurable quantities. By measuring five bushings in parallel and comparing results it was found that the loss is practically equal in all the bushings.

Fig. 20 gives the results of tests on six 44,000-volt condenser type bushings measured in parallel. The normal operating voltage stress to ground on these bushings when applied to apparatus on a 44,000 volt transmission system is approximately 25,000, and the maximum temperature which they will likely reach in service will not be over 75° C., due to conduction of heat from other parts of the apparatus. It will be seen, therefore, that even at 60 cycles the watts per bushing in normal operation will be certainly not over 10 and at 25 cycles not over three or four watts. It is interesting to note that the watt loss at temperatures below 75° C. varies practically as the frequency. It should also be noted that the increase in loss is very rapid at 100° C. or higher.

Fig. 21 shows the relation between charging current and temperature at 25 and 60 cycles on the same set of bushings, and Fig. 22 shows the relation between insulation resistance and temperature. In Fig. 22 the insulation resistance was measured at 10,000 volts direct current, and insulation resistance is plotted to logarithmic scale. The insulation resistance is 316 times as great at 25° C. as at 75° C.; 3160 times as great at 25° C. as at 100° C., and about 100,000 times as great at 25° C. as at 125° C. This change of insulation resistance is so great that the losses due to actual conduction are much greater than those due to the so-called hysteresis or dielectric losses. This explains the reason why the losses at both 60 and 25 cycles are so nearly the same at 125° C. At 75° C., or maximum possible operating temperature, the insulation resistance is 10,000 megohms.

FIG. 22.



Figs. 23 and 24 show the relation of dielectric loss to temperature and the relation of power factor to temperature for the same set of bushings. Again, it will be seen by these curves that the critical losses begin to manifest themselves at temperatures between 80° C. and 90° C.

Fig. 23.

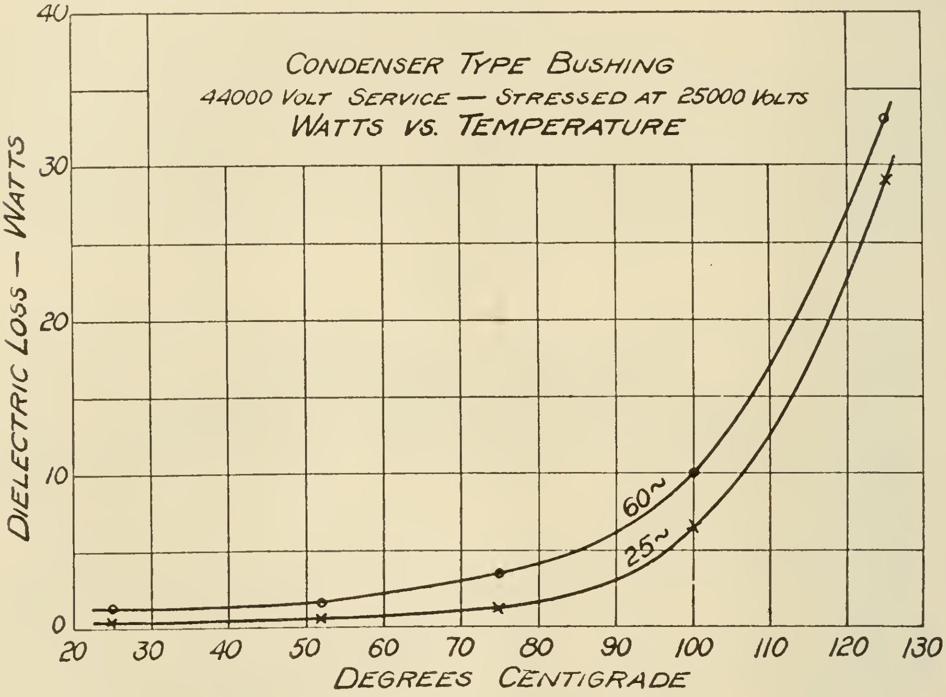


Fig. 24.

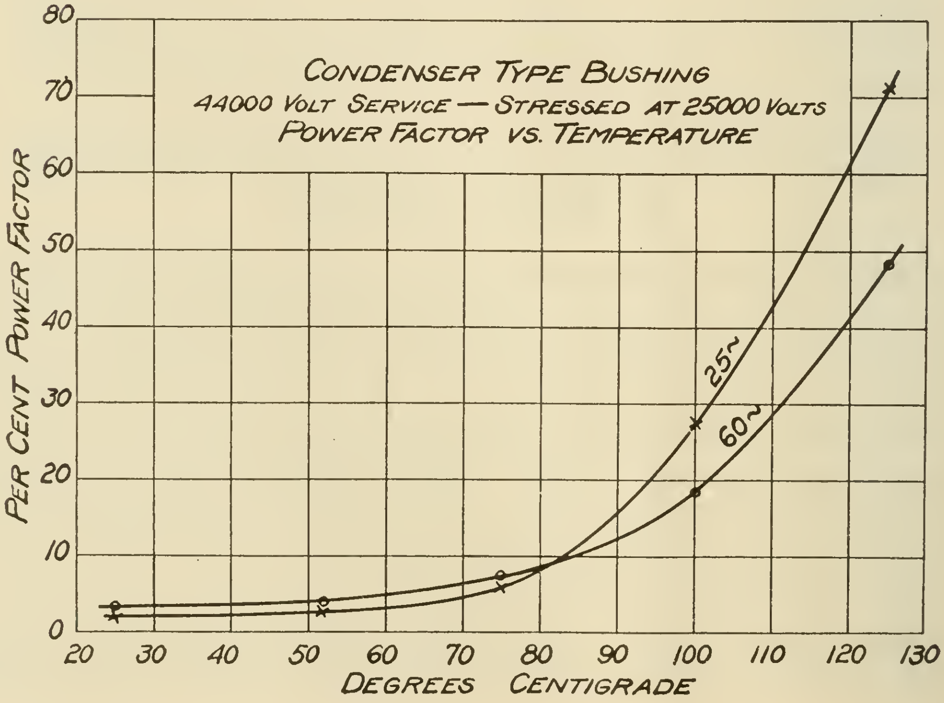
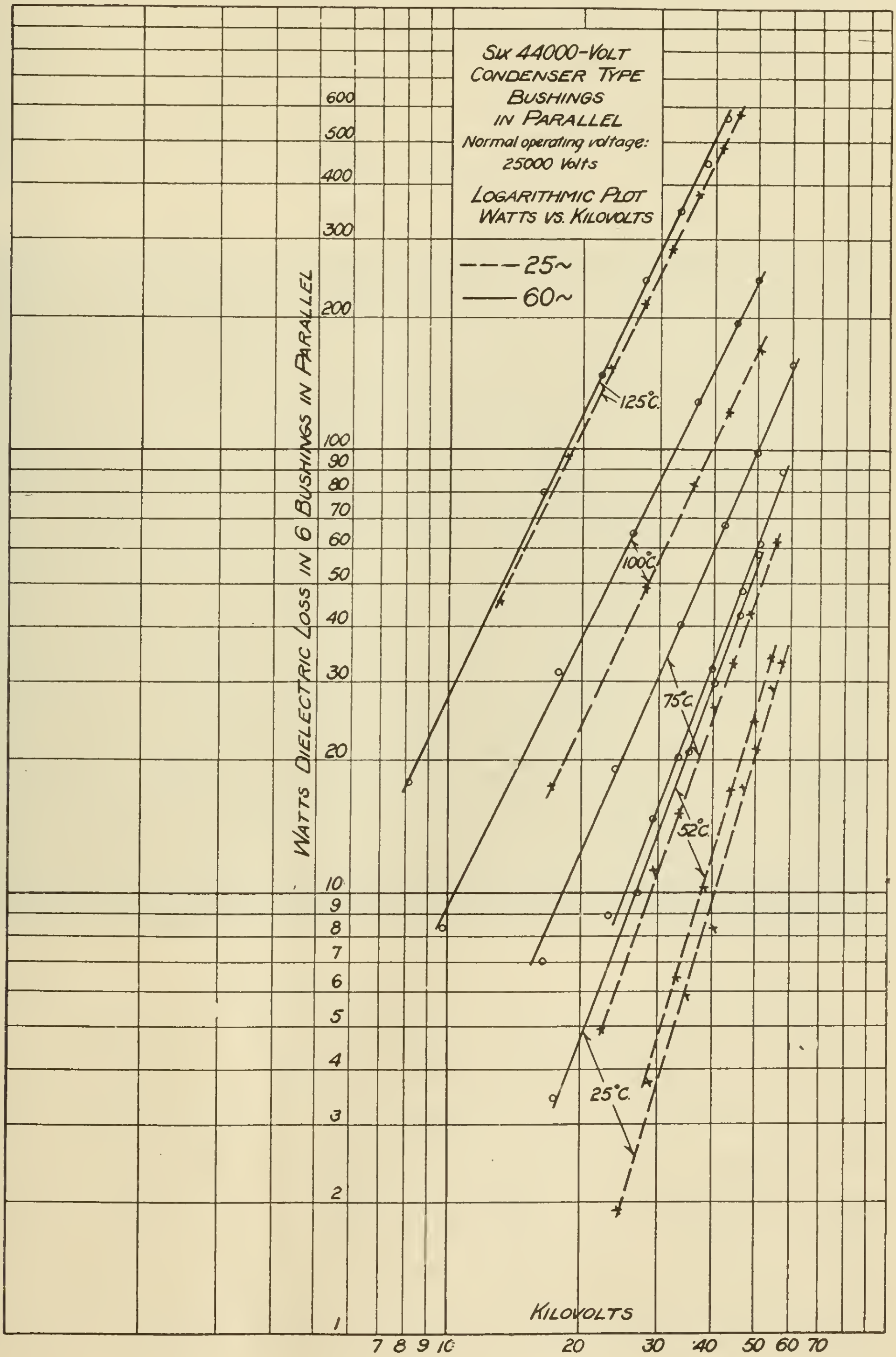


Fig. 25 is a logarithmic plot of the relation between dielectric loss and kilovolts applied to these same bushings, and the actual

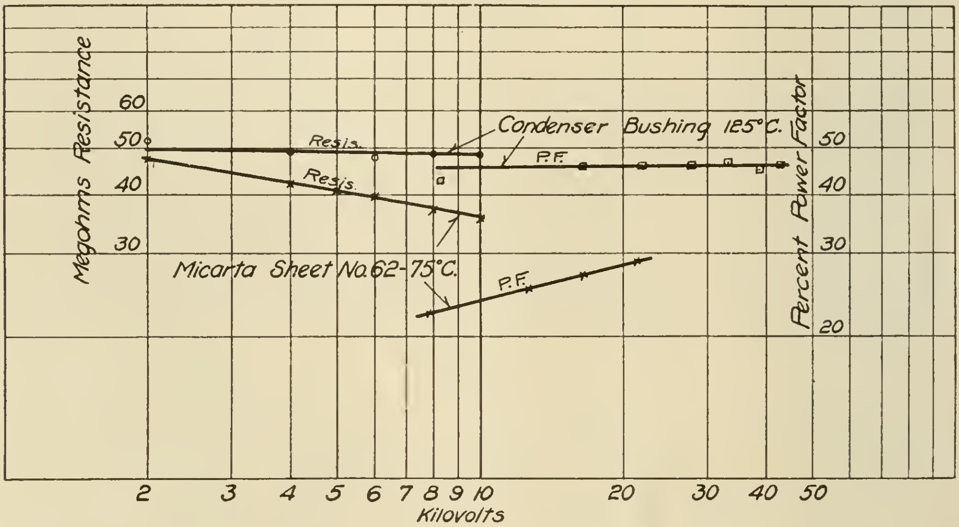
FIG. 25.



readings taken are plotted on these curves. It will be noted that the loss at 25 cycles is increased approximately 15 times by raising the temperature from 25° C. to 100° C. At 60 cycles the corresponding change is approximately six times.

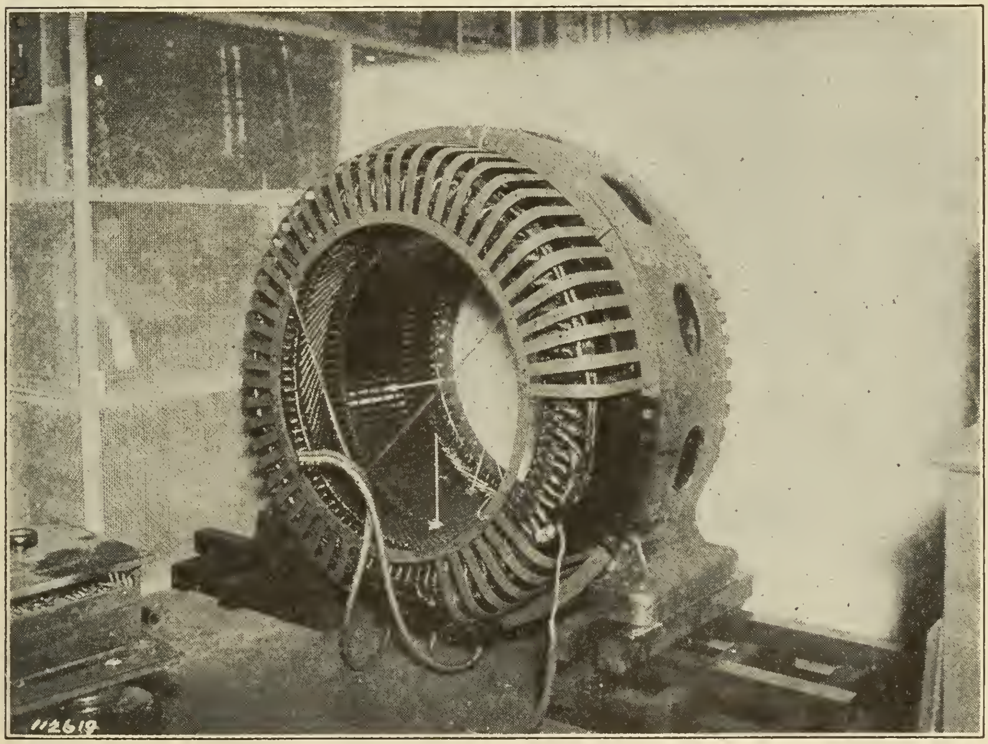
From the inspection of the logarithmic plot of the dielectric losses in micarta sheet No. 39 (Fig. 16) it is seen that at 100° C. the watts curve has a slope of 2.8 and a power factor of nearly unity, while at 29° C. the slope is 2.4 and the power factor is much lower. Since at the higher temperature the material more nearly resembles a conductor, the question might properly be asked, " Why does not the slope of the watts curve approach two as the power factor approaches unity with the increasing temperature, since the losses in conductors vary with the square of the voltage?"

FIG. 26.



The explanation is that the material is by no means a perfect conductor, even though the power factor is nearly unity. It is well known that in many insulating materials the ohmic resistance decreases as the impressed voltage used in measuring this resistance increases. In Fig. 26 are recorded measurements on two materials which are somewhat different in character; in one case (micarta sheet No. 62) the insulation resistance decreases with increased voltage used in its measurement, and in the other case (a condenser bushing) the insulation resistance remains practically constant as the measuring voltage is increased. The condenser bushing values are for a single bushing derived from the test on six bushings in parallel before referred to. In both cases the power factors are relatively high, this being a condition found at the higher temperatures at which both sets of measurements were made; and, furthermore, it will be seen that in the case of the condenser bushing the power factor remains practically constant with varying voltage, as well as the insulation resistance, while with the micarta sheet the power factor increases with increased voltage in about the same proportion as the insulation resistance decreases with increased voltage. This relation between insulation resistance and power factor, which, we believe, is here shown for the first time, appears to hold only for power factors of more than fifteen or twenty per cent. For materials having a lower power factor no such relation has been noticed. Micarta sheet No. 62 was chosen from one of the varieties which requires considerable processing in its manufacture, and the tests were made before this final processing. We have found it possible to carry the treatment of this material to a point where the insula-

FIG. 26-A.



400 KVA., 6000-volt, 50-cycle synchronous condenser stator on insulating base ready for test.

FIG. 27.

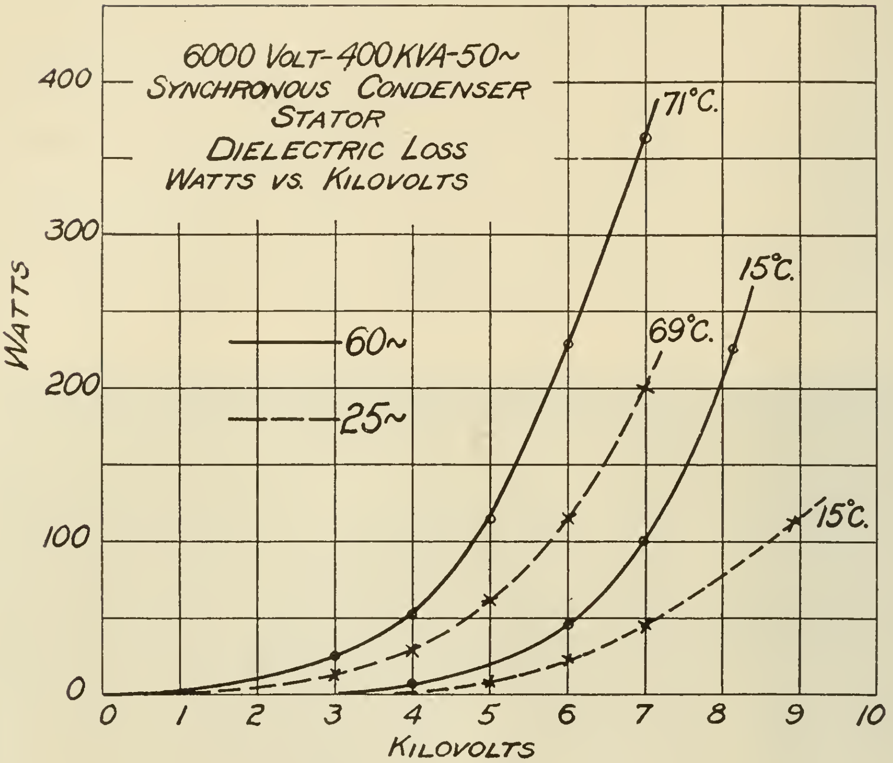
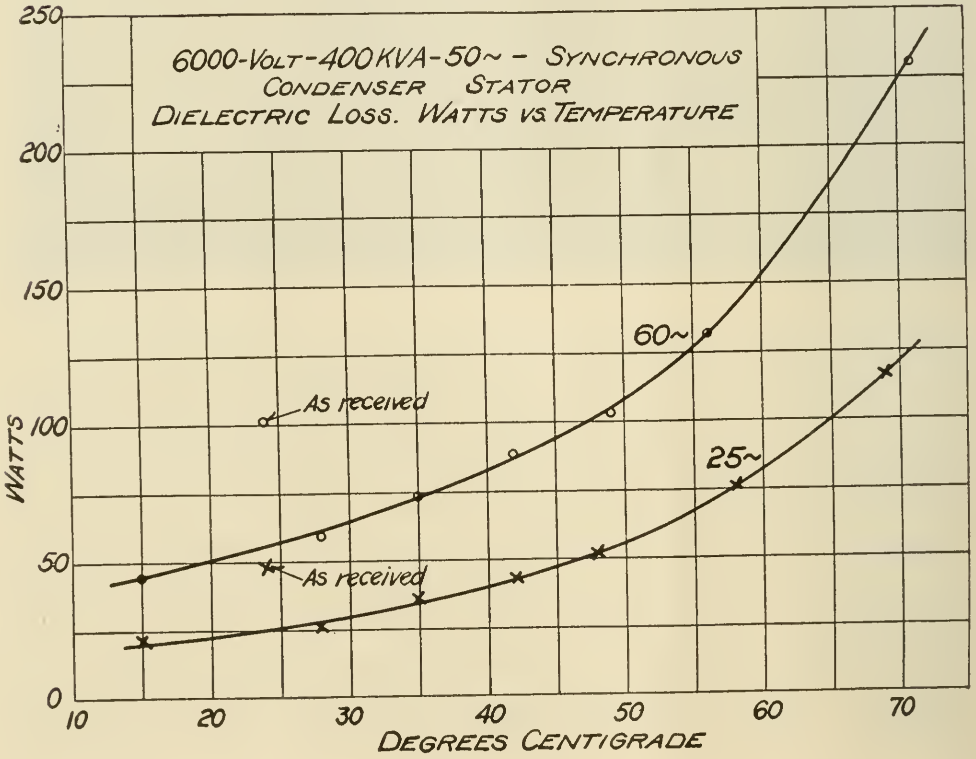

6000 VOLT-400 KVA-50~
SYNCHRONOUS CONDENSER
STATOR
DIELECTRIC LOSS
WATTS VS. KILOVOLTS
WATTS
400
300
200
100
0
0
1
2
3
4
5
6
7
8
9
10
KILOVOLTS
60~
25~
71°C.
69°C.
15°C.
15°C.

FIG. 28.


6000-VOLT-400 KVA-50~ - SYNCHRONOUS
CONDENSER STATOR
DIELECTRIC LOSS. WATTS VS. TEMPERATURE
WATTS
250
200
150
100
50
0
10
20
30
40
50
60
70
DEGREES CENTIGRADE
As received
As received
60~
25~

tion resistance and the power factor will remain constant with varying voltage. Particular attention is called to the fact that the sheet material in this curve is not in proper condition with regard to processing, and the condenser bushing measurements are at a temperature which would never exist in practice.

SYNCHRONOUS CONDENSER STATOR.

A synchronous condenser stator of 400 KVA. capacity, 6000 volts, 50 cycles, shown in Fig. 26 A, was measured and the results are given in curves Figs. Nos. 27, 28, 29, 30, and 31. During the test the machine was supported on a crib of well seasoned wood, which gave a very high insulation resistance from the machine to ground. It was found necessary to heat the winding by passing current through it, and when a temperature of approximately 70° C. was reached the heating was discontinued and the measurements started. Measurements of loss and power factor were made at atmospheric temperature before heating, as shown on Figs. 28 and 30. The temperature was measured both by thermometers and by the variation in the resistance of the winding and temperatures recorded are the averages of the temperatures measured. These temperatures are probably correct within two to five degrees. Loss tests were made with all windings connected in parallel and with the stress applied between the winding and the iron core. Special attention is called to the fact that the actual losses during normal operation of the machine will be not over one-third of the losses measured with the normal operating voltage applied to the insulation, since in normal operation the terminal ends of the winding only are subjected to this higher stress.

Fig. 27 shows the relation between the watt loss in the insulation and the voltage applied at 25 and at 60 cycles. Fifty cycles, the normal frequency rating of the machine, was not convenient for the tests.

Fig. 28 shows the relation between watt loss and temperature; Fig. 29 the relation between charging current and temperature; Fig. 30 the relation between power factor and temperature; and Fig. 31 the relation between insulation resistance and temperature. At 6000 volts the measured loss is about 0.007 watt per cubic centimetre at 15° C., 60 cycles, and about 0.0315 watt per cubic centimetre at 71° C., 60 cycles, but, as above indicated, the average

FIG. 29.

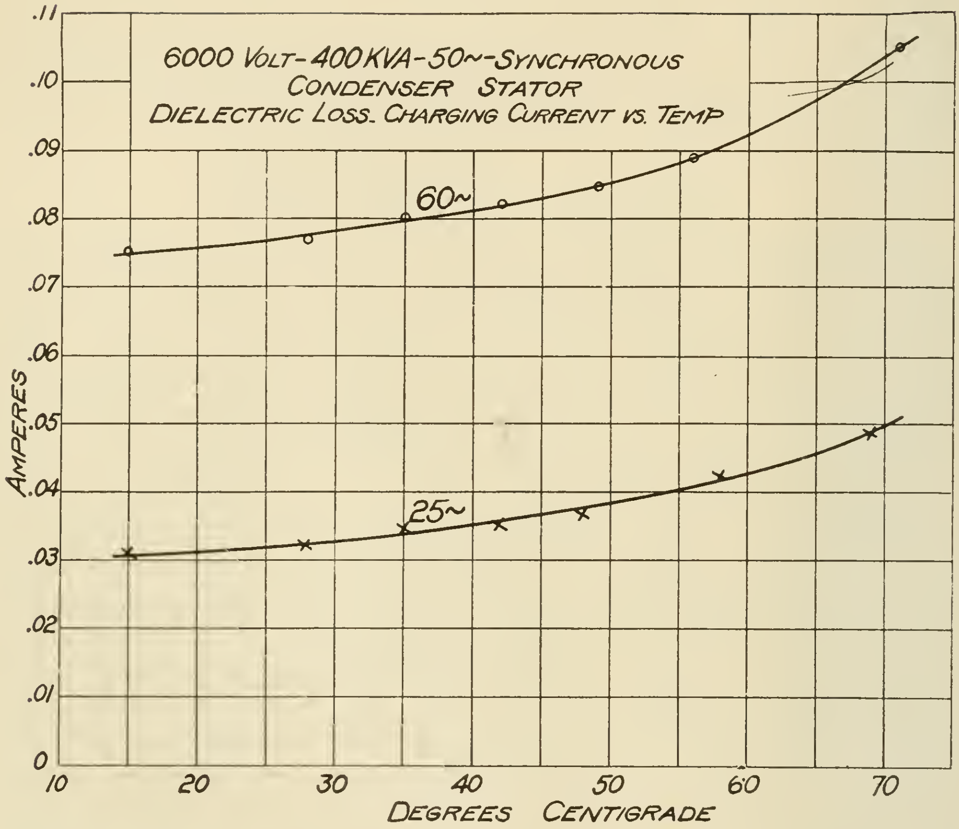

6000 VOLT-400 KVA-50~-SYNCHRONOUS
CONDENSER STATOR
DIELECTRIC LOSS. CHARGING CURRENT VS. TEMP
60~
25~
AMPERES
.11
.10
.09
.08
.07
.06
.05
.04
.03
.02
.01
0
10
20
30
40
50
60
70
DEGREES CENTIGRADE

FIG. 30.

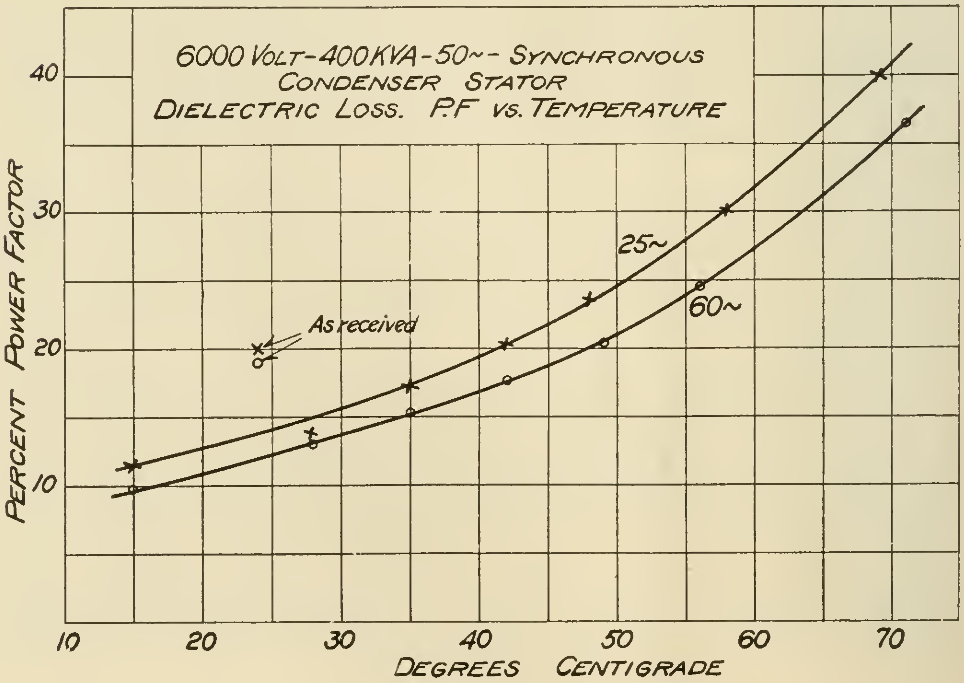

6000 VOLT-400 KVA-50~- SYNCHRONOUS
CONDENSER STATOR
DIELECTRIC LOSS. P.F VS. TEMPERATURE
25~
60~
As received
PERCENT POWER FACTOR
40
30
20
10
10
20
30
40
50
60
70
DEGREES CENTIGRADE

FIG. 31.

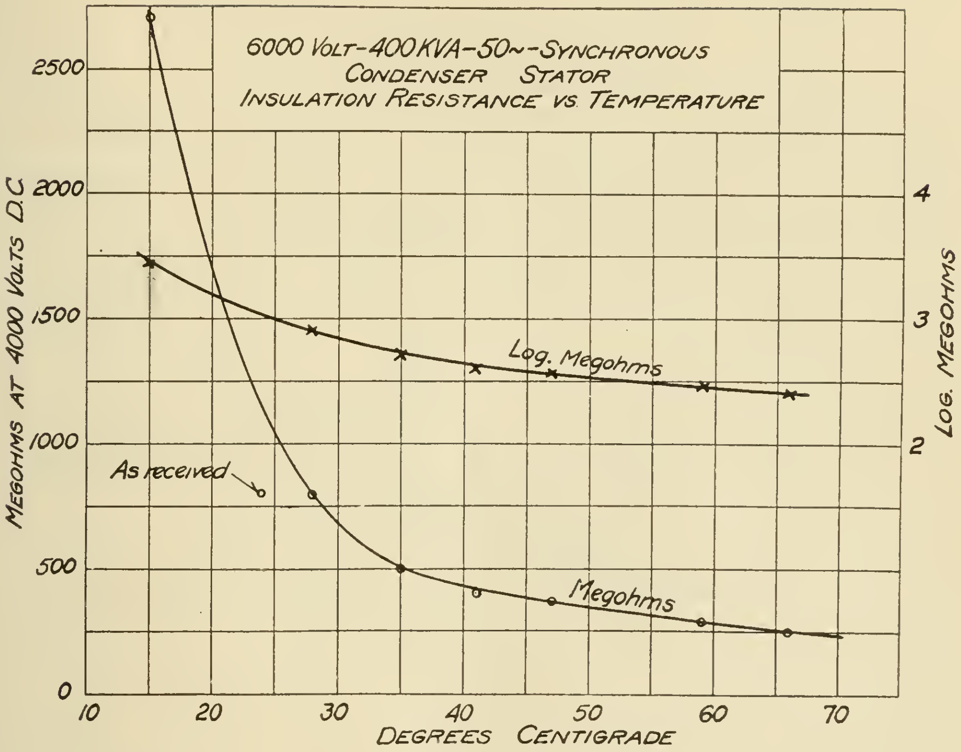

6000 VOLT-400 KVA-50~-SYNCHRONOUS
CONDENSER STATOR
INSULATION RESISTANCE VS. TEMPERATURE
MEGOHMS AT 4000 VOLTS D.C.
LOG. MEGOHMS
DEGREES CENTIGRADE
0
500
1000
1500
2000
2500
2
3
4
10
20
30
40
50
60
70
Log. Megohms
Megohms
As received

FIG. 32.

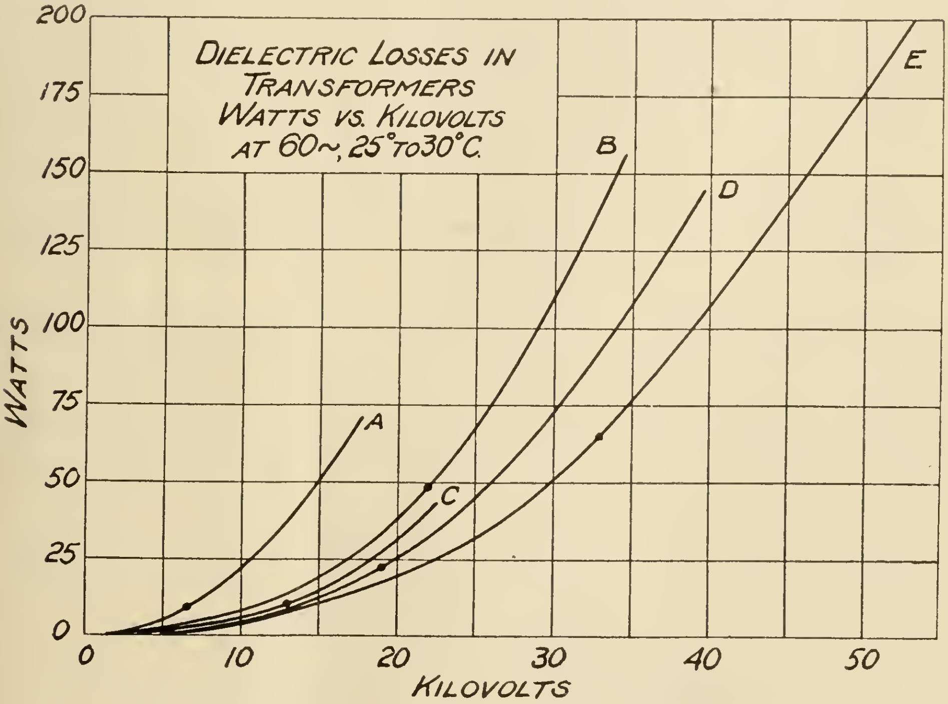

DIELECTRIC LOSSES IN
TRANSFORMERS
WATTS VS. KILOVOLTS
AT 60~, 25° TO 30° C.
WATTS
KILOVOLTS
0
25
50
75
100
125
150
175
200
0
10
20
30
40
50
A
B
C
D
E

FIG. 33.

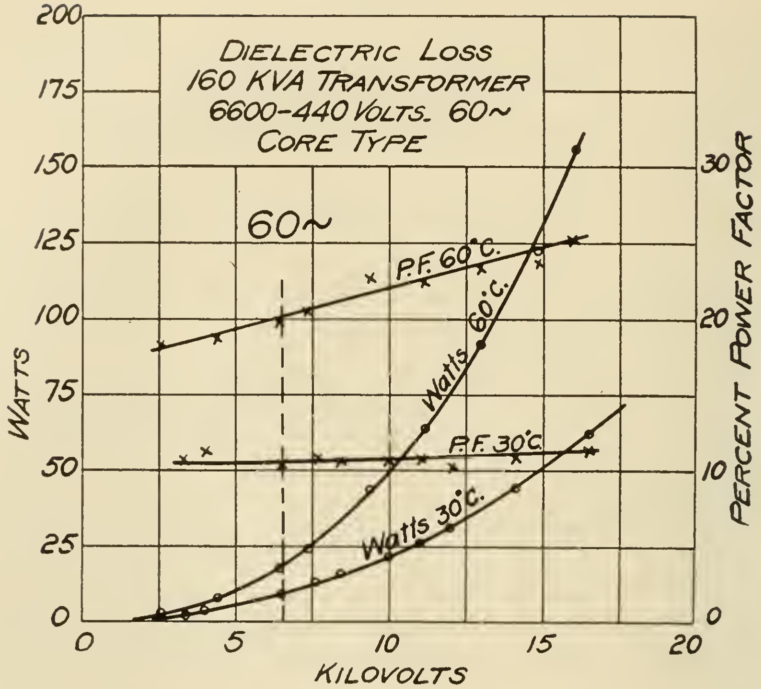
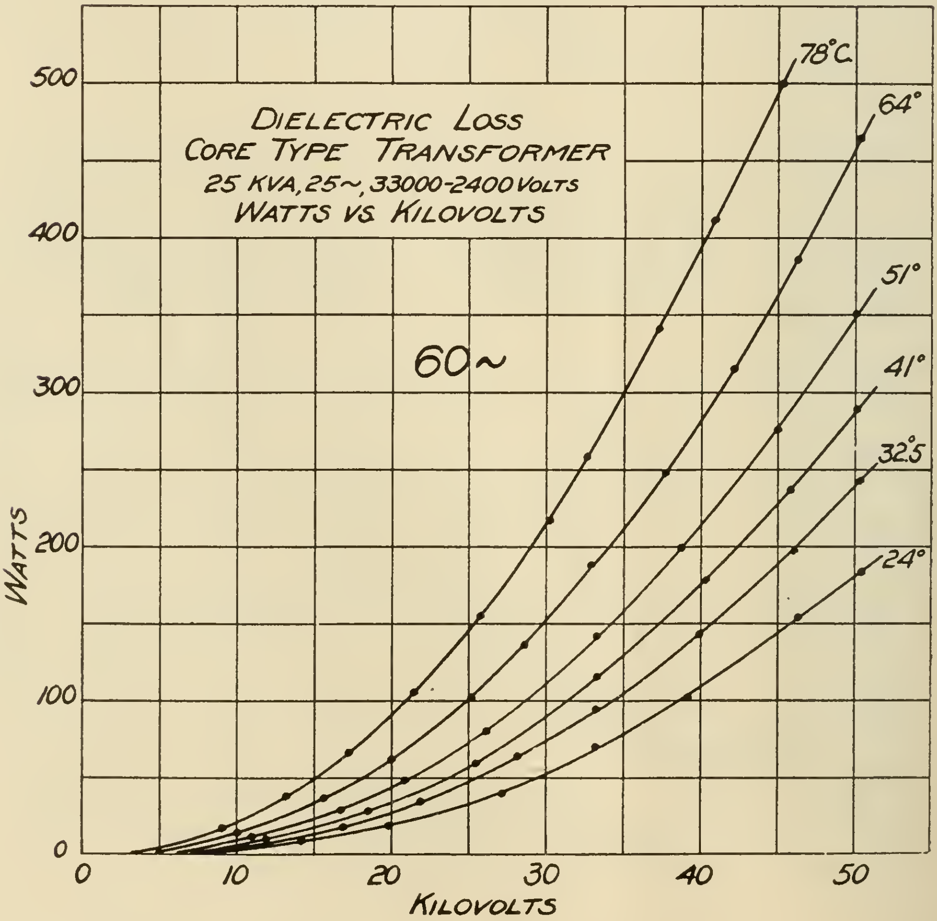

DIELECTRIC LOSS
160 KVA TRANSFORMER
6600-440 VOLTS. 60~
CORE TYPE
60~
P.F. 60°C.
Watts 60°C.
P.F. 30°C
Watts 30°C.
WATTS
PERCENT POWER FACTOR
KILOVOLTS
200
175
150
125
100
75
50
25
0
5
10
15
20
30
20
10
0

FIG. 34.

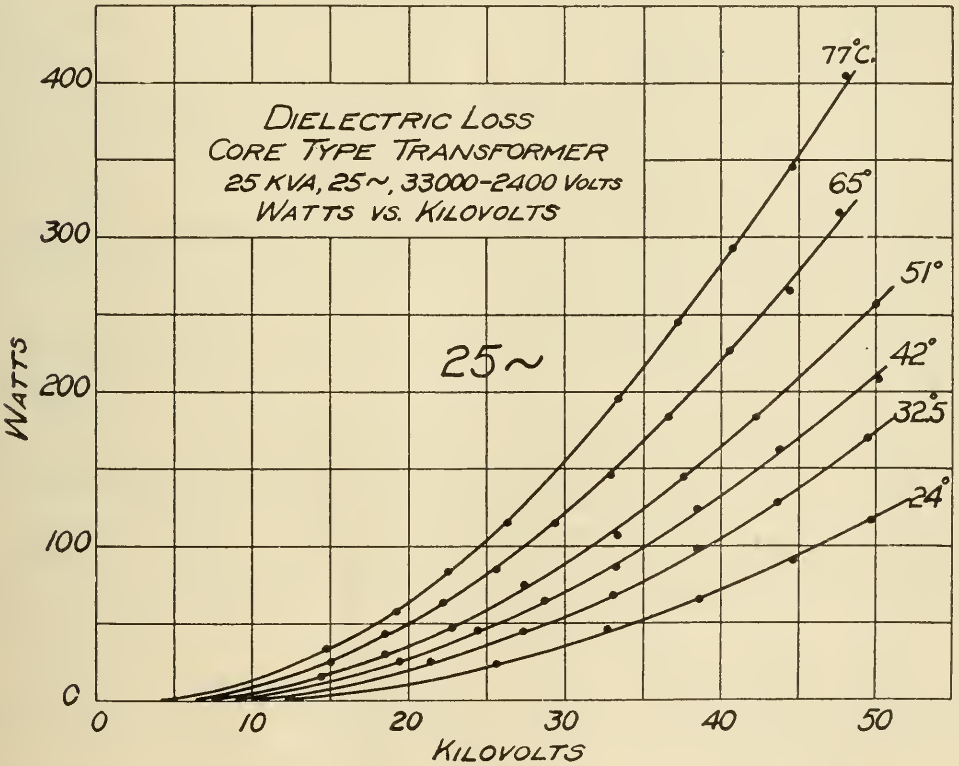

DIELECTRIC LOSS
CORE TYPE TRANSFORMER
25 KVA, 25~, 33000-2400 VOLTS
WATTS VS KILOVOLTS
60~
78°C.
64°
51°
41°
32°.5
24°
WATTS
KILOVOLTS
500
400
300
200
100
0
10
20
30
40
50

under actual operating conditions would be not over one-third of the above amounts.

TRANSFORMERS.

An extremely interesting set of measurements has been made on a number of transformers. In all cases the measurements were made from the high-tension winding to the low-tension winding and core connected together, or under the same conditions which prevail when dielectric tests are made on these devices. The transformers were, as in the case of the generator before described, placed on insulating supports. The variation in temperature was obtained in each case by loading the transformer as under normal conditions of test and determining the temperatures by thermometers and by the variation in the resistance of the winding. Loss measurements were made only when the temperature by resistance showed practically agreement with the temperatures taken by thermometers in the oil. Dielectric tests on the oil were made from time to time to insure that it was in good condition. As in the case of the tests on individual samples of material, it is fully realized that these tests should be taken as

Fig. 35.



indicative of the type of variations which will be found under the conditions and not as giving precise values which may be applied to other devices of the same kind. Attention is also especially called to the fact that, as in the case of the synchronous condenser stator, the actual losses in operation will be only approximately one-third of the losses indicated on the curves at normal operating voltage. These losses in service will vary with the particular connections used in operation and also with the condition of the insulation as indicated by the equation $W = KE^n$.

FIG. 36.

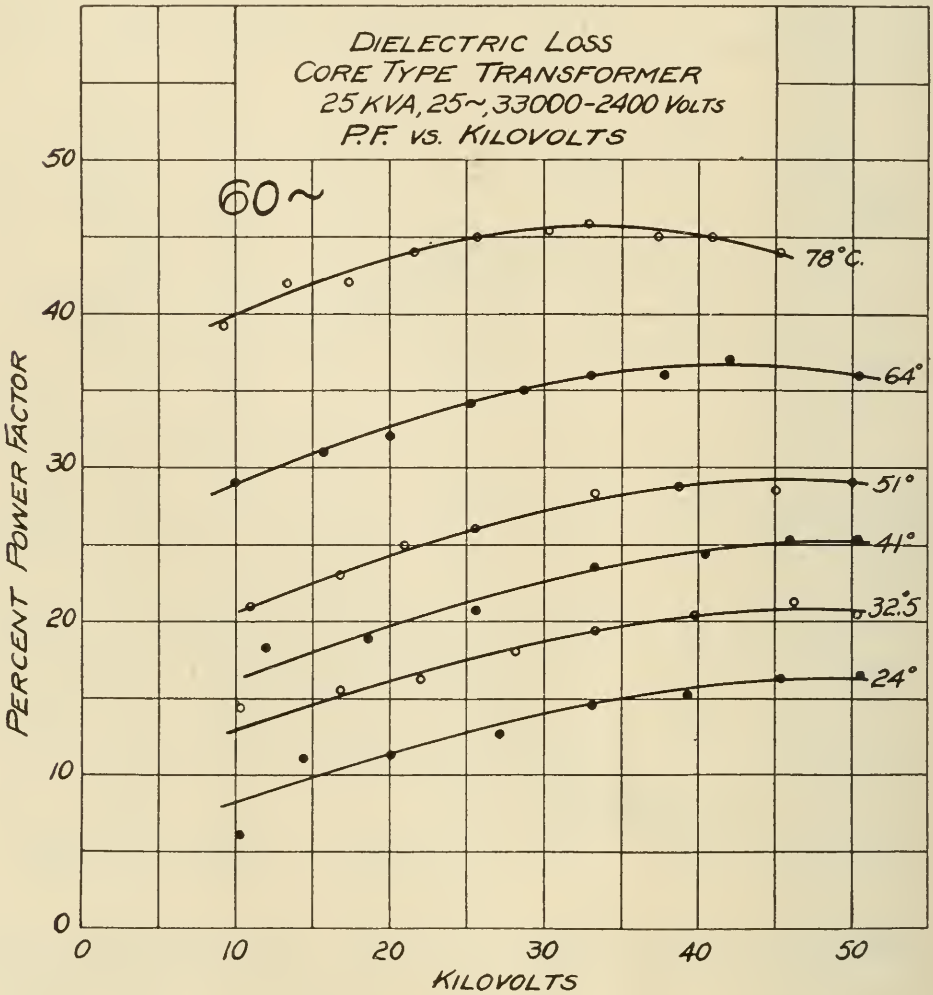


Fig. 32 gives the results of measurements at atmospheric temperature on five transformers, this curve showing the relation between watt loss and applied voltage. In each case the normal operating voltage of the transformer is indicated by the plotted point on the curve. The capacities and voltages of these transformers, all of which are of the core type, are given in the following table:

Transformer.	KVA.	Volts, H.T.	Volts, L.T.	Frequency.
A	160	6,600	440	60
B	100	22,000	2,400	60
C	50	13,000	220	60
D	25	19,000	440	60
E	25	33,000	2,400	25

Fig. 33 gives a typical curve taken on transformer "A" (Fig. 32), showing the relation of watt loss to applied voltage and power factor to applied voltage. The vertical line indicates the normal high-tension operating voltage of the transformer. Particular attention is called to the increased slope of the power factor curve at the higher temperature.

Figs. 34 and 35 give the complete record of the readings of watt loss and applied voltage at 60 cycles and 25 cycles respectively, with varying temperature. These curves are interesting as showing the general form taken by these curves and the relative consistency of the readings from which the curves are derived.

Figs. 36 and 37 give the power factor curves corresponding to the watt loss curves in Figs. 34 and 35.

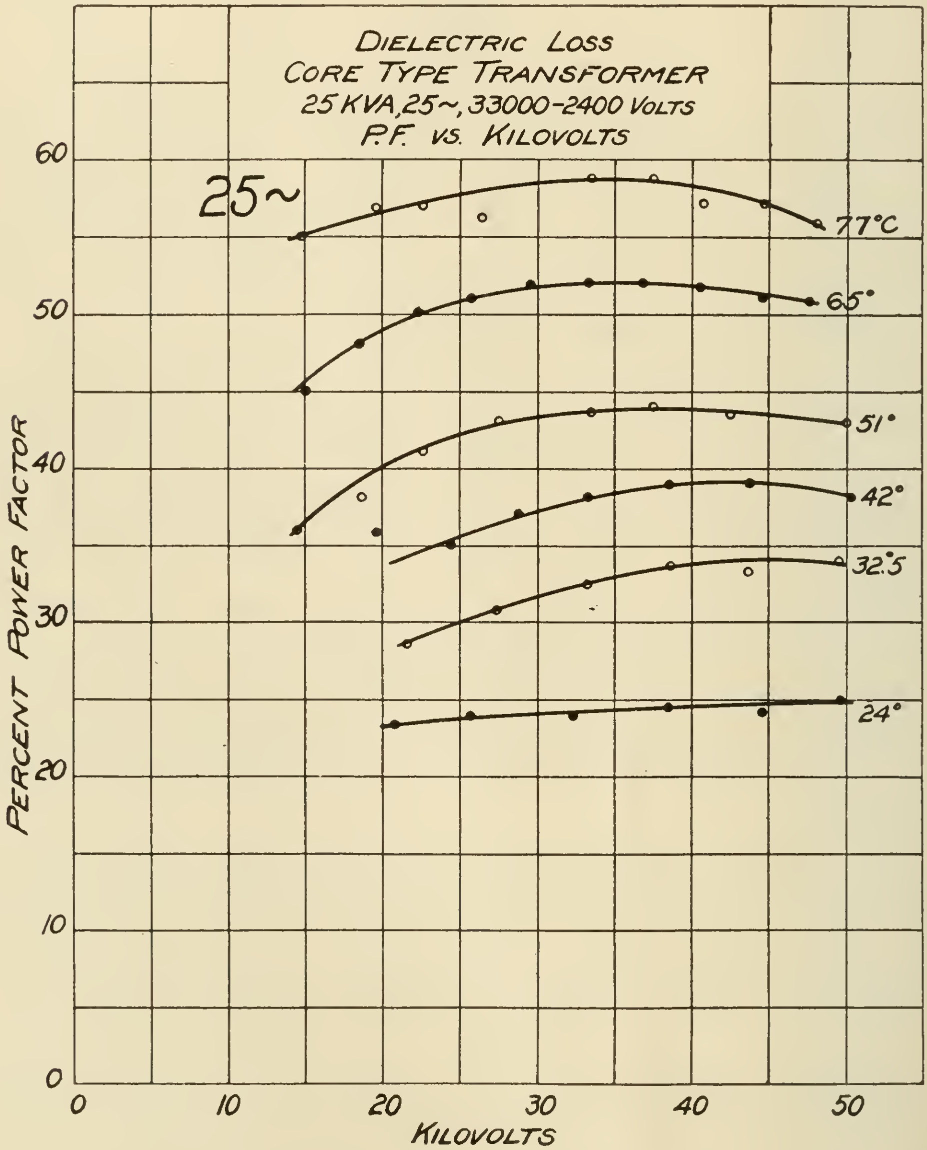
Fig. 38 gives the relation between power factor and temperature of transformer "E" at 25 and 60 cycles, and Fig. 39 the relation between watt loss and temperature at the same frequencies.

Fig. 40 gives the logarithmic plotting of the curves shown in Figs. 34 and 35. The plotting of these curves to the logarithmic scale gives the extremely interesting result that they become straight lines, and further shows that in no case was the insulation strained to a point near breakdown during the test.

From Fig. 40, Fig. 41 has been derived, showing the values of the constant K and the exponent n in the equation $W = KE^n$. The interesting fact to note in connection with Fig. 41 is that the watt loss increases more rapidly with voltage at low temperature than at high temperature.

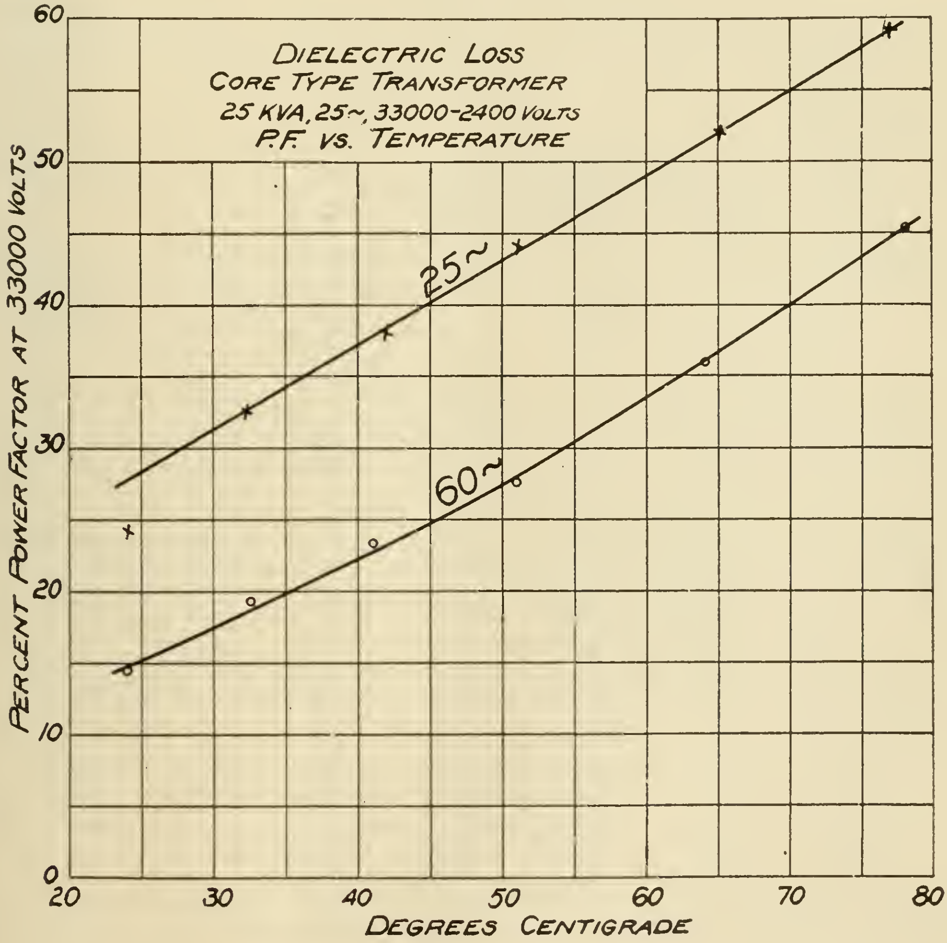
As before stated, the work which has been described has given us much valuable information with regard to specific problems in our manufacturing processes, and it has also shown that the dielectric loss test can be made a very valuable adjunct to the dielectric strength test and the insulation resistance test. It will probably never supersede the dielectric strength test as a control method in manufacturing operations, and it is doubtful whether it will ever be used as a criterion by the purchaser of electrical apparatus for the rejection or acceptance of the same. This method will without doubt be of more value to the manufacturer than to the user of electrical machinery.

FIG. 37.



Attention is again called to the fact that, while we have given the exact figures obtained in our measurement of losses, these can hardly be taken as generally representative of the classes tested, but we believe that they do show the type of results and the forms of curves which may be expected from such measurements. It should also be remembered that, while the losses in some materials and sometimes in samples of the same class of materials show very wide variation, the actual total losses are very small as compared with the iron losses, copper losses, etc., in the same class of apparatus, and are usually negligible, so far as the efficiency of the apparatus is concerned. It should also be noted that, even though the losses measured on some materials are many times those on others, the materials with the higher losses may be entirely satisfactory for the purposes for which they are used.

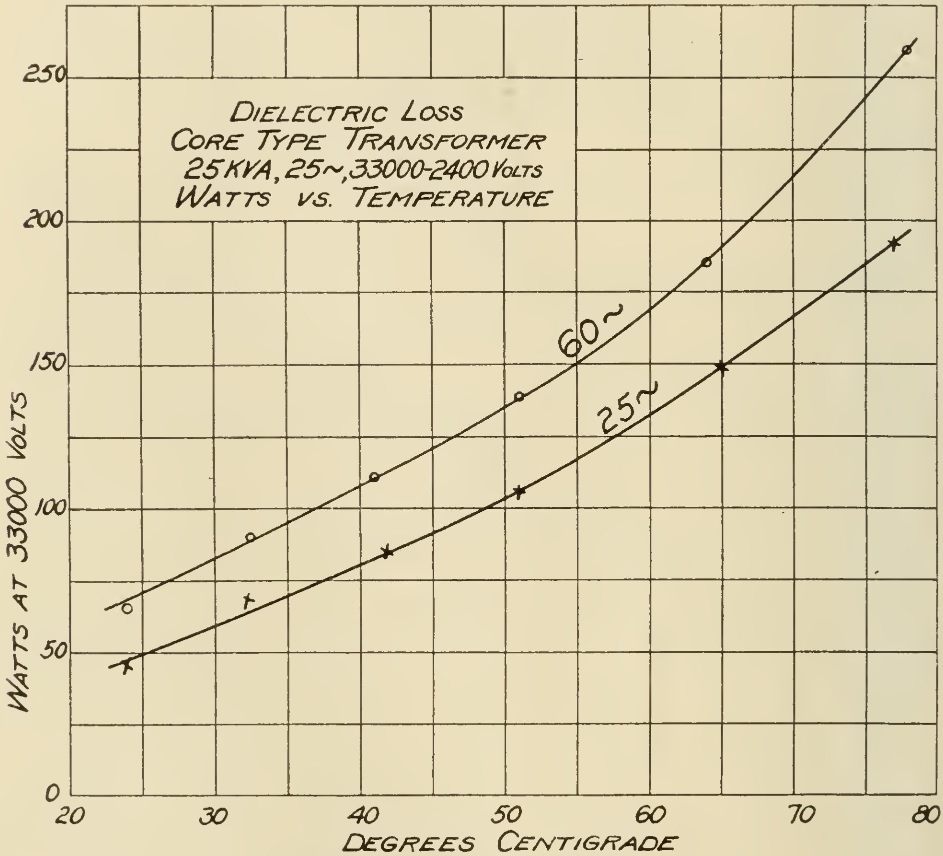
FIG. 38.



Our results would indicate that materials treated with varnishes and other compounds requiring drying or curing of any kind show markedly higher losses than the same materials saturated with fluid insulators, such as transformer oil. While the whole field has not by any means been covered, we believe this can be taken as a general law.

This test has many limitations, both on account of the comparatively elaborate methods necessary to make such measurements and on account of the fact that there are many insulators and many kinds of apparatus to which it is difficult to apply.

FIG. 39.



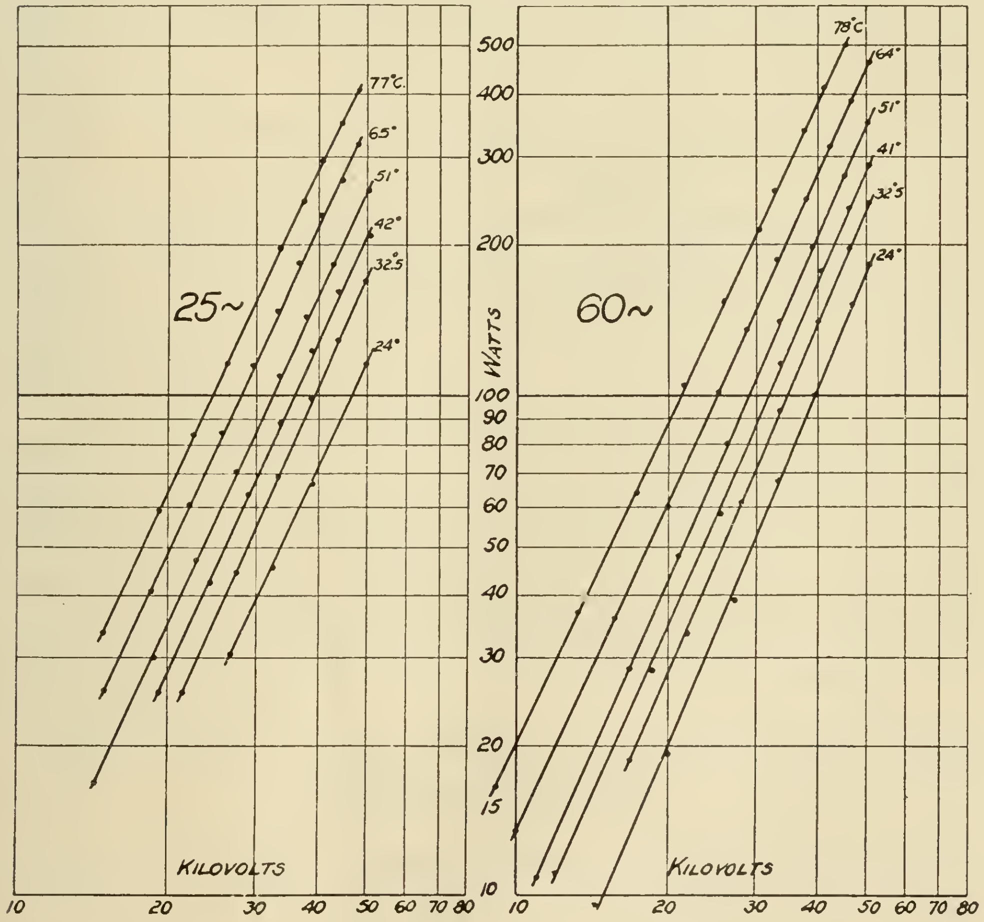
The method is very valuable for the evaluation of new materials and the control of the processing of many other materials. The changes in the losses, for example, are usually very great with the materials which require curing, whether this curing be the drying out of moisture, the oxidation of drying oils, or the carrying on of chemical changes which are very often necessary during the application of binders, fillers, and coatings, to other insulating material.

One of the most valuable characteristics of this test is that by its means, determinations may be made of the condition or quality of an insulating material or structure which would not stand the ordinary dielectric strength test without actually breaking the insulation down; and then by further treatment this same material or structure may be put into satisfactory condition. This test also confirms in a very striking way the well-known fact that the insulation of electrical apparatus is usually in its worst possible condition when apparatus is first put into service. The drying out due to service, as a rule, results in much better conditioning of the insulation than can be obtained during the manufacturing process without very extensive and expensive processing.

FIG. 40.

Logarithmic Plot, Watts vs. Kilovolts

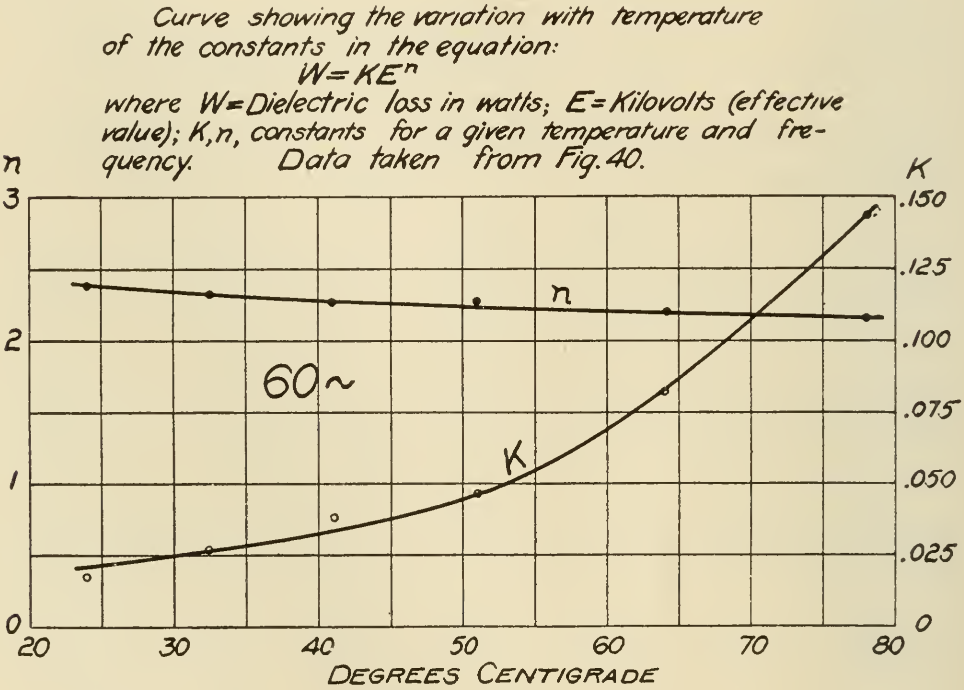
Dielectric Loss in a Core Type Transformer, 25 KVA, 25~, 33000-2400 Volts



In conclusion, it should be said that a more general application of the dielectric loss test will result in a much better knowledge of dielectrics in general, and the time is probably not far distant when such losses will regularly be measured by one or more of the methods which are being developed in the laboratories of the manufacturers and users of insulating material. By the use of these measurements, engineers will be enabled to figure their dielectric losses just as they now figure iron and copper losses, and they may have as definite specifications for the losses of insulating materials and insulated structures as they now have for iron and copper losses.

I would be unmindful of my opportunities if I did not, at this point, express my appreciation of the most excellent work which has been done by the men in the Research Division of the Westinghouse Electric and Manufacturing Company who have had to do with this investigation. Dr. Phillips Thomas, Messrs. D. G. Howard, C. A. Butman, J. E. Mateer, and others have done much of the work leading up to the final development of instruments and methods. Mr. H. L. Cole has collected and edited the theoretical considerations which are given in this paper, and has also carried out practically all of the actual tests which have been recorded. Prof. H. B. Smith, of Worcester Polytechnic Institute, has given valuable counsel and help during the progress of the work.

FIG. 41.



Curve showing the variation with temperature of the constants in the equation:

$$W = KE^n$$

where W = Dielectric loss in watts; E = Kilovolts (effective value); K, n, constants for a given temperature and frequency. Data taken from Fig. 40.

ENZYMES IN THE FERMENTATION INDUSTRIES.*

BY

LEO WALLERSTEIN,

Wallerstein Laboratories, New York City.
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It is self-evident that the organic substance that is burned up into carbonic acid by this respiration means a loss of substance which amounts, in well-conducted malting, to about 5 per cent.

For economic reasons, it must be to the brewer's interest to reduce burning-up of his malt substance by breathing to a minimum. By retarding or moderating the growth of the embryo, through limiting the air supply and by comparatively low temperature, a sufficiently large production of enzymes may be produced in the malting process without an inordinate loss in substance through excess of growth.

The last step in malting is the kilning process. After the germination has sufficiently proceeded, it is interrupted by kilning. The green malt is first deprived of part of its moisture-content at lower temperatures, and then the kilning is finished at temperatures ranging from 175° to 210° F. The heating and kilning are done, as a general rule, by direct fire gases in large kilns, where the material is put in several stories so that a gradual heating takes place.

The objects of the kilning process are: (1) to interrupt germination; (2) to remove excess moisture, so that the malt will become transportable and in condition for storage; and (3) the production of the characteristic malt flavor and aroma.

The malt grain, after kilning, has gained in volume, and is about 30 per cent. larger than the barley corn.

I wish to point to some significant changes of enzymatic nature during kilning. In this rather long-drawn-out process of drying and kilning of the wet malt the enzymes, the production of which, of course, was the main objective of the malting operations, are found to run the gamut of a wide range of more and more raised temperatures, even finally rising to 85° to 98° C.

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*Concluded from page 556, May issue.

Now, we have repeatedly noted the limitations of enzymes in enduring high temperatures, and we should therefore be curious to know what happens to our enzymes during the kilning.

At first, enzymatic actions are much on the lines as in malting; but when temperatures of 45° to 50° have been reached, developments in the sense of enzymatic reversions play a great rôle.

For instance, invert-sugar in part becomes again converted to saccharose; and some fermentable sugars are re-transformed into unfermentable polysaccharides. Similarly there are reversions which the albuminous bodies undergo that had previously already been degraded; they are re-transformed into real coagulable albumins. To some extent even the actual destruction of enzymes occurs in kilning.

Amylase is not affected by temperatures that will affect proteases, while the cytase, which, as we have seen, has to perform the work of breaking down the starch-cell walls, is completely destroyed during the kilning.

MASHING PROCESS.

The next step is the preparation of the wort by the mashing process.

The largest part of the malt endosperm is still insoluble in water, but in such form that most of it can now be readily transformed into soluble compounds during mashing.

The object of the mashing process, therefore, is to make such insoluble substances soluble by continuing and regulating the enzyme actions started during malting in such manner that the dissolved substances will be finally found in the finished wort, in the desired quantities and proportions.

For that purpose the crushed or ground malt is mashed in with water of suitable temperature (as a general rule, about 40° to 50° C.), and under these conditions the enzymes contained in our malt at once begin their work. The proteolytic enzymes act on the proteins, the amylase begins the conversion of the soluble starch into maltose and dextrines, the phytase attacks the organic phosphor compounds.

As pointed out before, the action of the amylase depends to a great extent on the temperatures, and we can therefore influence at will the ratio of maltose to dextrines in the wort.

It is apparent that it is one of the arts of the brewer to so regulate his mashing temperatures that the resulting wort will have the proper composition for the specific type of beer he desires to produce.

For beers which will be higher in alcohol and low in residual extractive substances the mashing process is so conducted that amylase will form large quantities of the readily fermentable maltose, by mashing for a considerable time at a temperature between 55° and 60° C. On the other hand, if it is desirable to make beers low in alcohol and high in unfermented extract, the mashing process is so modified that part of the diastase is destroyed and the rest allowed to act at higher temperatures, thereby producing a wort rich in dextrines.

At this stage I wish to point out that the malt will, under proper conditions, saccharify not only its own starch but additionally large quantities of added starchy material.

In the American practice of brewing, about one-third of the total material is used in the form of unmalted cereals, of which a separate mash is made; the amylase contained in the malt readily converts this extra quantity of gelatinized starch into maltose and dextrines.

In the distilling industry it is desirable, for economy's sake, to work with as little malt as possible. It is therefore obviously advantageous to employ a malt which is very rich in amylase, and for the purpose of distillery malts are kiln-dried very carefully, so as not to destroy any appreciable quantities of the amylase. In distillery practice, one part of good malt should be able to convert, besides its own starch, eight to nine parts of corn, the starch of which has previously been gelatinized by cooking.

As we have pointed out before, the action of all enzymes is greatly dependent on the reaction of the medium, be it acid, neutral, or alkaline.

In this connection, the composition of the brewing water is of far-reaching influence on the diastatic and proteolytic action during the mashing process. If we prepare a wort with distilled water, we find the same to react slightly acid toward litmus, due to its content of primary phosphates; in practice, the mineral salts contained in the brewing water have a tendency to either increase this acid or decrease it, and thereby influence the course of the mashing process. Alkaline waters—those containing calcium, magnesium, or sodium carbonate—have a retarding influence on the enzymatic action, while waters containing calcium sulphate and calcium chloride, through their interaction with the phosphates, increase the acidity of the mash and have a favorable influence on the action of the enzymes.

In this respect I refer to the work of Fernbach and Huber, as well as of Windisch and Derz.

During the mashing process the action of the proteolytic enzymes is also of great importance, and the proper running off of the wort (its filtration) depends to a large extent on the way these enzymes have performed their work.

On the other hand, if, through carelessness, the mashing process is not conducted correctly (that is, if either the amylase or the proteolytic enzymes are not allowed to act under conditions to do their work properly), a great many difficulties are liable to occur in the subsequent stages of the process.

For instance, one of the difficulties which formerly gave much trouble to the brewer is starch turbidity, due to incomplete saccharification, caused, for example, by faulty mashing temperature, which caused destruction of the amylase before same had done its complete work. Nowadays it is a rare occurrence.

Of more frequent occurrence is the turbid running off of the wort, and, in consequence, difficult clarifications of the beers. This fault is usually due to an insufficient modification of the proteins during the malting process, particularly if in mashing the action of the proteolytic enzymes has not been sufficiently facilitated.

For such malts it has been found necessary to conduct the mashing process for several hours at a temperature of about 40° to 50° C., to give the proteolytic enzymes favorable conditions of time and temperatures. But there are also cases, though rare, where very high mashing temperatures from the beginning are indicated; for instance, in working up malts which might be termed "over-malted."

All this only confirms what I pointed out, that mashing is really a continuation and a bringing to a conclusion of all those changes that have been started in the process of malting.

After the mashing process is completed, the wort is separated from the dregs and boiled with hops. Thereby all the enzymes contained in the wort are destroyed and a separation of the coagulable albuminoids takes place.

FERMENTATION.

The boiled wort is cooled to a temperature of 7° to 10° C. and about one pound of fairly thick yeast per barrel of 31 gallons added.

After a short time the yeast begins to sprout, fermentation sets in, and a gradual splitting up of the sugar into alcohol and carbonic acid gas takes place.

Simple as this reaction appears, it is really a highly complex process, and only within recent times has it been recognized that it is the result of a number of complicated enzyme reactions.

For more than two centuries have the most astute scientific minds been engaged in the task of elucidating the laws underlying the phenomena of fermentation, and a short review of the history of our knowledge of fermentation may not be out of place.

In 1680, Leeuwenhoek, the Dutch scientist, who had designed a magnifying glass of marvellous perfection for the time, proved that yeast was composed of small globular bodies, which he thought were possibly of a vegetable nature; but he drew no further inference as to their function.

The fact that only sweet liquors were liable to ferment had been observed and specially dwelt upon by J. J. Becher, in 1682, but it was not until one hundred years later that Appert, a French cook, hit upon an ingenious method for conserving sugar-containing articles of food by preventing their fermentation.

By Appert's method, which has made its author famous, articles such as grape-juice, etc., were put into completely filled bottles. The bottles were then placed in water, which was gradually heated to boiling, and were then tightly corked and allowed to cool, when, of course, the contracting liquid left a vacuum space near the top. Naturally the grape-juice, etc., thus preserved kept indefinitely, but was again liable to souring or fermenting after the bottle had been opened.

Appert and his contemporaries concluded that contact with air was the cause of fermentation or souring of fruit juices and similar substances.

This theory that fermentation was caused by oxygen was further developed and championed by the famous French chemist, Gay-Lussac.

About 1835–1837, or seventy years after Appert's discovery, several German and French chemists successfully disproved the oxygen theory; it was especially Theodor Schwann who in 1837 demonstrated that if air is heated, or passed through highly corrosive liquids, like strong sulphuric acid, it loses its power to incite fermentation. Sugary liquids previously heated and brought in contact with air so treated did not ferment, while with ordinary air they did show fermentation.

At this time (1836) Berzelius had already expressed himself in the following highly significant manner: "In processes observable in animal or vegetable life, certain bodies possess the faculty of influencing compounds in a manner entirely different from ordinary chemical affinity, by causing in such compounds a decomposition or rearrangement of parts without themselves or without any constituents of theirs partaking therein." Berzelius proposed for these phenomena the term "catalytic action."

Liebig, three years later, in 1839, said: "Fermentation is not a physiological or life process, but is caused by the peculiar property of a ferment contained in yeast, which ferment is in a state of constant motion, changing and transferring this motion to the sugar." He called this action "contact action," because the ferment infects sugar with its own instability by contact.

Liebig's statement, emanating from such high authority, dominated chemical thought for twenty years or so, and therefore scant attention was paid to other interesting observations, as, for instance, to the fact, proved by Schroeder and Dusch, that sugar-containing solutions could be indefinitely preserved in contact with air, if the latter has been previously filtered through cotton wool. I will mention also the significant observation by Hemholtz that alcohol fermentation is not transmitted through membranes.

Then, in 1857, Pasteur made his famous announcement that in every case of alcoholic fermentation the development and increase of cells could be observed; that fermentation represented a life act, a process dependent on and indissolubly accompanying the life-cycle of an organism; and that it was not a phenomenon of any so-called contact action, wherein the transformation of sugar is caused by the presence of a ferment which itself remained unaffected. This was in strongest contrast to Liebig's theory, who had all along made his contact substance appear a product of destruction or disintegration of the life of the cell, whereas Pasteur laid emphasis exclusively on the growth of the cell and made the fermentation appear a direct function of the physiological phase.

In support of his view, and especially to bring proof that contact action with bodies derived from yeast could be had outside the living yeast-cell, Liebig showed that a water extract made from yeast possessed the property of converting cane-sugar quantitatively into invert-sugar, and explained that possibly the yeast-cell might, in its life process, produce those contact bodies that cause the cleavage of sugar into alcohol and carbonic acid, but that the life process as such had no relation to fermentation. On the other hand, Pasteur, even two years after Liebig's death, still maintained (1875) that the chemical process of fermentation was essentiallly dependent on the life act, with which it begins and ends.

To-day we may say that, although Pasteur's great work has firmly established the fact that fermentation is inseparably connected with the life and growth processes of the yeast-cell, yet the distinction indicated by Liebig between the substance causing fermentation (enzyme) and the yeast-cell which produces it has been borne out since.

The first man definitely to formulate this merely chemical enzyme action as being basic for all fermentation processes was really Moritz Traube, who (1858) stated: "Yeast acts upon sugar not in a physiological way, but simply by ferments, which it separates, similarly to sprouting seeds that secrete diastase, or almonds which give off emulsine."

Traube had not brought proof to support his theory in the field of alcohol fermentation; in fact, though Liebig himself had succeeded in performing enzymatic operations (invertase) by means of yeast extract, real fermentation outside the living yeast-cell remained unaccomplished. As early as 1846, Luedersdorff, also Schmidt, had tried to destroy yeast-cells by crushing, but no fermentation resulted when they added the destroyed cells to a sugar solution. Other investigators tried to obtain juice from yeast by pressure, but never succeeded in getting the liquid entirely free from living yeast-cells. Others, like Naegeli, applied certain menstruums, such as glycerine, for extracting the contents of the yeast-cell. All experiments were unsuccessful and modified fermentation theories always followed.

To furnish the correct answer was reserved to E. Buchner.

who, in 1897, by more exact work and technical perfection, prepared an extract or juice from yeast entirely free from living yeast-cells. Buchner triturated yeast with quartz sand and infusorial earth, and then subjected the mass to high pressure in an hydraulic press. The resulting yeast juice contains zymase, an enzyme that will produce alcoholic fermentation outside the living cell.

Zymase is not the product of disintegration of the living yeast-cell, but, on the contrary, its formation is most intimately connected with, and dependent on, the growth of the living cell and its physiological functions.

Inasmuch as this cell-freed yeast juice, as produced by Buchner, will cause alcoholic fermentation, the theory of Liebig that fermentation in itself, as a merely chemical process, is separable from the physiological functions of the cell, stands strongly supported.

Returning to our short description of practical brewing operations, you will recall that we had pitched the wort with yeast. Fermentation in the case of lager beers, we find, is completed after eight to ten days, after which the yeast settles to the bottom of the vat.

Microscopical examination would show that, after pitching, each drop of wort contains about forty yeast-cells, while during fermentation the number of yeast-cells has increased to four or five times the original quantity. (One gramme of pressed yeast represents approximately 2,000,000 cells.)

It is a noteworthy fact that in the same wort and under the same temperature conditions ultimately the same number of yeast-cells is found after fermentation, immaterial of the larger or smaller quantity of yeast originally added to the wort.

The most striking change which takes place during the eight- to ten-day period of fermentation is the decomposition of the fermentable carbohydrates into alcohol and carbonic acid. However, besides this main reaction, a great many other changes have occurred.

On the one hand, part of the peptones, amino-acids, and mineral substances have been taken out of the wort by the yeast and used for the building up of new protoplasms, while, on the other hand, protoplasmic substances and products of metabolism are diffused from the yeast-cell into the beer; for instance, certain organic acids, glycerine, aromatic substances, etc., all of which are found in the finished beer.

The yeast itself, which settles to the bottom of the fermentation vat, is used for subsequent brews.

This short outline refers to bottom fermentation beers, so-called " lager " beers. Another process, wherein the yeast rises to the top of the fermenting liquor, from which it is skimmed for the next fermentation, is termed " top fermentation process," and is used for ales, stouts, and similar brews.

Top fermentation is conducted at much higher temperatures, frequently at 20° to 25° C.

The yeasts used for these two processes represent two distinct varieties, called bottom fermenting yeast and top fermenting yeast; although they are hardly distinguishable under the microscope, they show great variance of work at each other's temperature conditions.

Besides the two yeast races mentioned, there exist a large number of other yeasts, so-called " wild " yeasts.

First to investigate the merits and coexistence of these various races was the late Prof. E. C. Hansen, who, in 1883, showed that, beside the culture yeast, a number of these wild races did exist, and that the latter were far more frequently causes of trouble in brewing than any disease caused by bacteria infection. Hansen's classical investigations led him to the invention of his famous pure culture system, whereby pure races of yeast have been cultivated and the most far-reaching and beneficial change for the fermentation industries resulted.

The basis of Hansen's ingenious method is the isolation of individual yeast-cells and by rigid precautions propagating them in absolute race purity.

I have mentioned before that when the wort is pitched with normal yeast quantities it contains about forty cells to one drop. Hansen diluted this mixture so that only the third or fourth drop could contain one yeast-cell, and by adding to a number of bottles containing sterilized wort just one drop per bottle he made it possible that not any bottle could contain more than a single yeast-cell.

After two or three days, this individual cell had sufficiently multiplied to form a colony, which was carefully examined as to its race purity, and, if approved, was employed for gradually producing a large quantity of yeast.

Other methods have since been proposed for pure yeast cultures which have been very successful; as, for instance, Lindner's droplet culture.

Let us discuss in some detail this enzyme-producing yeast-cell, its property and its mode of reproduction.

The yeast-cell, though probably more closely studied than any other living organism, offers no striking features in its life-cycle differing from any other similar plant-cell. In its propagation it reproduces itself by budding; that is, a small protuberance appears on the cell, quickly increases in size, and after it has attained the dimensions of the parent cell it becomes detached, and the separated daughter cell in turn reproduces itself by the same process.

Like all other living organisms, the yeast must have oxygen for its existence, without which it will unfailingly perish.

In the course of Pasteur's studies on the breathing of the yeast the savant had given a highly original and entirely new insight into the whole question of respiration in the low organisms.

Pasteur discovered that with a copious supply of oxygen yeast would propagate and cause fermentation, but that with oxygen completely shut off it not only continued to grow but its fermentative capacity was much higher than in the case where fresh air was supplied.

Pasteur defined fermentation as life in the absence of air. Then how is it that organisms do not perish under these conditions, according to our previous statement? Pasteur discovered that a large class of lower organisms depend for their breathing supply on oxygen, which they derive from organic compounds, albumins, etc., which they split up and thus forcibly compel to furnish them with the oxygen needed. These organisms he called "anaërobic," as distinguished from "aërobic," or those using atmospheric oxygen.

Here in Philadelphia, in your municipal experiment station for sewage disposal, at Spring Garden, you have a centre from which, as applied to the special field of sewage disposal, concise knowledge and proof of these conditions have been spread everywhere.

The anaërobic bacteria, in their breaking-up work, cause putrefaction, as is evidenced by the bad smells of sulphur compounds, which are volatile decomposition products of the albuminous bodies which they attack. It was stated in the records of the Spring Garden investigations, extending mainly through the years 1909 to 1911, that in one cubic centimetre, say twenty to twenty-five drops of sewage, no less than three to four million of these anaërobic bacteria were counted, all voraciously bent upon devouring the albuminous food contained in the city sewage.

These anaërobic bacteria, however, cannot possibly live where even only a very moderate amount of free oxygen is dissolved in the liquid. Therefore the gist of all sewage disposal into rivers or water lies in the maintaining of a slight oxygen balance so that eventually only the aërobic bacteria might exist. These aërobic bacteria or fungi likewise feed on albumin, etc., but they lack the faculty of breaking up these albumins for breathing purposes.

Pasteur stated that yeast was an organism, capable of living under both kinds of conditions, but that it was only as an anaërobe that it functioned at all as an alcoholic ferment. I quote Pasteur's own words: "Fermentation by yeast (that is to say, by the type of ferments properly so called) is presented to us, in a word, as the direct consequences of the processes of nutrition, assimilation, and life, when these are carried on without the agency of free oxygen."

Many tests have since been undertaken further to investigate these phenomena; for instance, H. Buchner and Rapp experimented to determine whether sugar could be fed to yeast without forming alcohol, under conditions where the maximum access of air came into contact with each particle of yeast. They found that under these conditions one-seventh of the sugar was used for respiration, while six-sevenths was transformed into alcohol.

The important practical problem, whether in brewing and alcohol fermentation generally it were better to work with more or less air or with no air at all, has been definitely solved in the sense in which Pasteur already answered this question, that, with abundant air furnished, the sprouting or body growth of yeast goes on at a much faster rate than when less or no air is provided, but that the fermentative power, pound for pound, is much larger when air is excluded.

These and similar investigations have been very helpful in developing the large industrial branch of compressed yeast manufacture. In Europe, especially in England, Germany, France, etc., yeast is very largely employed instead of baking powder in bread-making, and the process of yeast manufacture by "aëration" dominates.

I will now in a few brief remarks refer to the food requirements of yeast. For this phase we are well prepared because of our insight gained into the changes and accomplishments in the steeping, malting, and mashing processes. The mash after boiling constitutes an ideal liquid for the nourishment of yeast. We have the various carbohydrates in the proper form; there are also the amino-acids and other nitrogenous bodies so important for the building up of the protoplasm of the cells; considering that yeast in the dry form consists of more than half of albuminous matters, equivalent to about 8 per cent. of nitrogen. The wort also contains the very necessary phosphates and potassium, magnesium, and calcium salts.

You will remember that the wort, before the yeast was added, had been boiled, and therefore all the enzymes contained therein were destroyed.

This simplifies matters in so far as all enzyme functions from now on are within the yeast-cell or, at any rate, originate there.

Let us be thankful even for this little simplification. The process in itself is so complicated that any simplification is more than welcome. Slowly the scientific investigators are now elucidating the complex working of the stupendous organization seated in the yeast-cell and how the cell manages its enzymatic staff; already the presence of seventeen enzymes therein has been established, but very likely there are a great many more.

There is catalase, which decomposes hydrogen peroxide; there is maltase, the enzyme that converts maltose; there is invertase, the enzyme that splits up cane-sugar and converts it into dextrose and lævulose; there is glycogenase, which attacks glycogen; and others. However, there is no amylase present, and starch degradation is henceforth precluded. Of the greatest importance are the proteolytic enzymes of the yeast. The principal one, also contained in Buchner's press juice, called endotryptase, has been diligently studied, and ranks in general importance with pepsin and trypsin, but is really different from both. It is very powerful, digests fibrin, egg-albumin, casein, etc. It degrades albumin very much like trypsin; in fact, it goes even further in splitting up of albumin into simpler bodies; its optimum working conditions, however, are more like those under which pepsin acts, as it requires a slightly acid medium for its best activity.

Under normal cell conditions, endotryptase will not diffuse from the living yeast-cell, and therefore its activity takes place only within the cell itself.

If for any reasons the fermentative activity of the cells has ceased—for instance, because of abnormal temperatures or lack of sugar—then this powerful endotryptase forms a certain menace to the life action of the yeast itself. It begins to attack and to decompose the protein compounds of the cell itself, including the enzymes, especially those responsible for the fermentation (zymase). This process is called " yeast autolysis."

The destructive action of the endotryptase towards zymase is also apparent in Buchner's press juice, which on standing gradually loses its fermenting powers.

Buchner, however, made the remarkable observation that if to the pressed juice a quantity of pressed juice which has been previously boiled is added, the zymase will remain active for a much longer time. He came to the conclusion that the gradual destruction of the zymase on standing is due to the activity of the endotryptase, which decomposes the zymase; and that during the boiling of the juice an antitryptase is formed which prevents the endotryptase from attacking the zymase. He also proved that this anti-tryptase will protect casein and other albuminous substances from being attacked by the endotryptase.

I now wish to describe in further detail the workings of the " zymase."

The zymase, as stated before, is contained in Buchner's pressed yeast juice, also in Lebedew's maceration juice.

Lebedew's method is as follows: Brewers' pressed yeast is spread out in thin layers, about 1 cm., and dried at a temperature of 25° to 30° C., which takes about two days. The slow drying so changes the cell conditions that when this dried yeast is macerated with a small quantity of water at about 35° C. for four hours the zymase becomes diffusible and goes in solution. It is filtered, and the filtrate contains, besides other yeast enzymes, also zymase. I have here a sample of such maceration juice, and will show you a few experiments with it.

By adding to sugar solution some of the maceration juice, fermentation was induced. Another experiment showed the instantaneous decomposition of hydrogen peroxide by the catalase contained in the Lebedew maceration juice.

Recent investigations, particularly those of Harden and Young, have done much to give us a clearer understanding of the mechanism of the working conditions of this zymase.

One of the facts established by these investigators was that by filtering the fresh juice at a pressure of 50 atmospheres through a Chamberland filter, which was impregnated with a 10 per cent. gelatine solution, they could separate the juice into two parts, one remaining on the filter and a clear liquid passing through. They found that with neither of the two separate parts could they bring about fermentation, but made the highly important discovery that if both are mixed the fermentative power was again restored in the mixture. They also found the fact that the filtrate could even be boiled and still retain its power to cause fermentation after mixing same with the residue that had remained on the filter.

Harden and Young thereby established the important fact that zymase needs for its working efficiency an "activator," which they termed "co-enzyme," and which can be separated from zymase by proper filtration, and which is not destroyed by boiling.

Another momentous result from the work of the same investigators was to ascertain the intimate relation of the phosphates to the action of the zymase.

First, they had observed that when sugar solutions were undergoing fermentation by the addition of Buchner's pressed juice they could, by adding alkaline phosphates, bring about an increase in the evolution of the carbonic acid gas.

They then discovered the fact that a definite relation exists between the amount of phosphates added and the volume of carbonic acid evolved. In other words, they proved that when the alkaline phosphates were added in a certain quantity formation of alcohol would be engendered in analogous amounts.

The authors have given the following explanation, which is now generally accepted:

The zymase does not act on the sugar directly, but on a rather loose combination of sugar with a compound of sugar and phosphate, the hexose-phosphate. This intermediary loose combination is the result of the action of an enzyme, phosphatese, which is contained in Buchner's pressed yeast juice, and has the power to form same out of two molecules of sugar and two molecules of phosphate. Only after this loose compound has been formed will the zymase begin its fermentative action by attacking it and splitting off the one molecule of sugar, decomposing the latter into carbonic acid and alcohol, while the hexose-phosphate, which is composed of two molecules of phosphate and only one of sugar and which is a rather stable compound, remains.

$$2C_6H_{12}O_6 + 2PO_4HR_2 = 2CO_2 + 2C_2H_5OH + 2H_2O + C_6H_{10}O_4\ (PO_4R_2)_2$$

This residual hexose-phosphate is now acted on by another enzyme, the phosphatase, which again disrupts the hexose-phosphate into dextrose and phosphate.

$$C_6H_{10}O_4\ (PO_4R_2)_2 + 2H_2O = C_6H_{12}O_6 + 2PO_4HR_2$$

Thus having restored the phosphate and half of the dextrose to their original form, the cycle of operation begins anew by the "phosphatase" acting upon the two molecules of phosphate and two molecules of dextrose to form the above combination once more. Thus, by an endless chain of operations, the same amount of phosphates is made to do a large fermentation work over and over again.

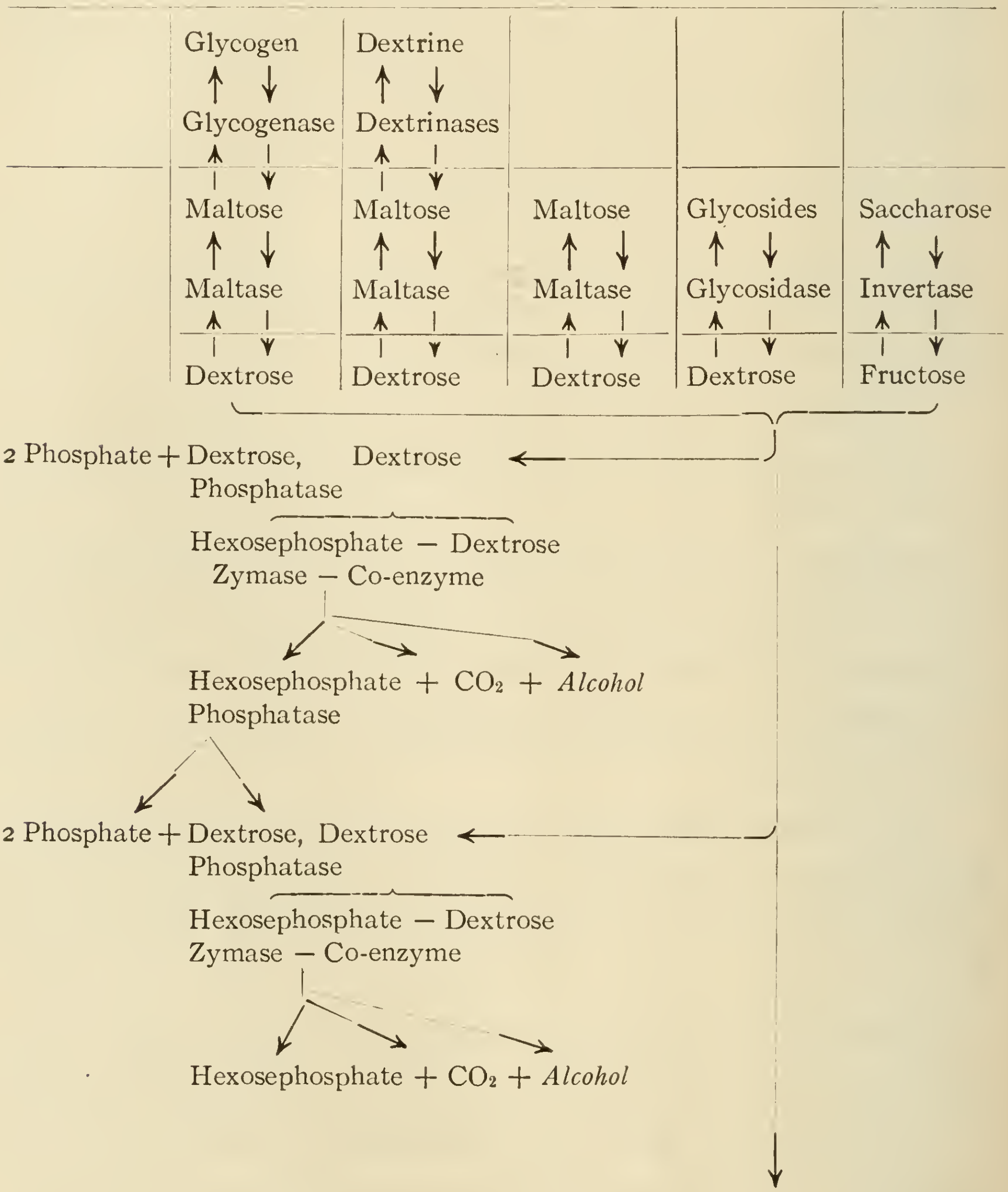
This cycle of fermentation functions is illustrated in graphic form on page 730.

It is worthy of note that the main or end reaction in alcoholic fermentation, the cleavage of sugar into carbonic acid and ethyl alcohol, was already formulated by the renowned chemist, Gay-Lussac, a hundred years ago, and has remained unshaken ever since.

It would lead too far to enter upon a discussion of all the intermediary processes which lead to the above simple result, and in the course of which a number of bodies appear on the scene, such as methyl-glyoxal, lactic acid, acet-aldehyde, formic acid, oxy-acetone, pyruvic acid, glycerine, etc.—some ultimately detached as waste products—of which we now know that they are landmarks of those intricate processes.

A number of fermentation schedules have been advanced for elucidating this field. Thus, according to Schade and Ehrlich, an isomeric lactic acid is first formed from the sugar, the acid subsequently splitting up into acetaldehyde and formic acid, which two bodies, by interaction, then form alcohol and carbonic acid.

However, many probabilities speak for the greater correctness of the view advanced by Kostytschew and Neuberg, that the preliminary cleavage of sugar leads first to pyruvic acid and loosely-combined hydrogen; the pyruvic acid is then by an enzyme, carboxylase, split into acet-aldehyde and carbonic acid, and the acet-aldehyde becomes promptly reduced to alcohol by the hydrogen previously activated by means of a reductase.



I have previously stated that besides alcohol and carbonic acid other substances are formed during alcoholic fermentation, and among these I wish to specially call attention to the higher alcohols, or fusel oils.

For a long time the formation of these fusel oils could not be explained; within recent years, however, this mystery has been completely cleared up by the remarkable investigations of Felix Ehrlich. We have noted before that the wort contained considerable quantities of amino-acids, and he proved that these higher alcohols are due to a decomposition of these amino-acids. The yeast has the faculty to split off the ammonia from the amino-acids, using same as nitrogenous food, and at the same time the corresponding higher alcohols and carbonic acid gas are formed.

The important fact that the yeast-cell also has the power to synthesize its albumin for its cell substance directly from the ammonia, sugar, and inorganic salts is not new and had already been observed by Pasteur. This synthesis of albuminous substances with ammonia as nitrogen source is probably also brought about by enzyme action within the yeast-cell.

It has of late become of great importance in Germany, where enormous quantities of yeast are now manufactured from ammonium sulphate, phosphates, and sugar, the yeast being dried and used for cattle feed. We have here a process in which, in less than 24 hours, large quantities of inorganic nitrogen are changed into a form readily available for feeding purposes. This process has assumed great economic importance.

In quite an analogous way the commercial production of ethyl alcohol depends up zymase action, and the enzyme actions involved are very closely related to those of the brewing industry.

The commercial production of alcohol in this country starts either with corn as a raw material or with molasses. In using corn as a raw material, as previously stated, the starch therein is saccharified by means of malt and changed into maltose and dextrines. This saccharified mash without filtration is then allowed to undergo alcoholic fermentation. If this fermentation is well and properly conducted, the residual amylase is not destroyed and will saccharify the major part of the dextrines contained in the mash, which then will also be split into alcohol and CO_2 by the fermenting yeast. Fermentation temperatures are much higher than those employed in brewing, the temperatures usually running approximately from 20° to 30° C. The yeast used belongs to the top fermenting variety.

The other important commercial raw material in the production of alcohol is molasses. During the fermentation of molasses mashes the yeast must first secrete sufficient quantities of invertase to change the cane-sugar into invert-sugar, which is then readily split up into alcohol and carbon dioxide.

Entirely different are the enzyme actions involved in the production of vinegar, lactic acid, and butyric acid.

Two processes are known for the production of vinegar: The slow vinegar production, called the "Orleans" process, and the "Quick" vinegar process (*"Schnellessigfabrikation"*). In the case of vinegar the enzyme action is an oxidizing action. By the instrumentality of acetic acid bacteria which produce the enzyme alcoholase, the dilute alcohol (5 to 12 per cent.) is directly oxidized by atmospheric oxygen to acetic acid. In the formation of lactic acid, the lactic acid bacteria form an enzyme which at relatively high temperature (up to 50° C.) changes the sugars into lactic acid. Similar is the production of butyric acid by the butyric acid bacteria.

Let us now again return to our practical brewing operations.

The fermented beer is stored for a number of weeks, during which time it clarifies, and is then finished by being impregnated with carbonic acid gas and filtered.

The part of the beer which is to be sold as bottled beer is then pasteurized by heating in the bottle to 140° to 150° F. for about half an hour.

Formerly beer was served from the keg, the bottling done being primitive. Such beer, whether bottled or not, was intended to be, and was, as a rule, consumed shortly after it left the brewery. With the development of the bottling industry, however, a change in the methods of consumption ensued. Bottled beer began to be shipped long distances from the brewery, and, instead of being consumed soon after it left the brewery, was kept for considerable periods of time.

It was soon found the well-brewed beers under conditions of long shipment and storage developed microörganic growths. The brewers therefore adopted the process of pasteurization; *i.e.,* the beer in the bottle was subjected to a temperature of from 140° to 150° F. for about half an hour. While pasteurization prevented the growth of microörganisms, it was found that pasteurized beer was particularly sensitive to cold and was unstable.

It is customary in this country to drink bottled beer very cold, the bottles being usually kept on ice for a considerable time before consumption.

This chilling causes beers to deteriorate, lose their brilliancy, and to become hazy or cloudy. Prolonged keeping at ordinary temperatures has much the same effect on brilliant bottled beers. While pasteurized bottled beers vary in their keeping qualities, as a rule, if kept at ordinary temperatures for from six weeks to three months, they become hazy and cloudy, and then usually deposit a sediment.

The production of a beer which did not cloud on ice, and which would remain brilliant in the bottle and without sedimentation, was the important technical problem which faced the brewer in recent years. Many theories were put forward to explain the causes of this peculiar behavior; the general opinion was that the trouble was due to undesirable albuminoids contained in the beer.

To overcome these difficulties, the brewers tried to eliminate as much as possible these so-called "undesirable albuminoids" by the freezing-out process; that is, subjecting the beer to very cold temperatures and subsequent filtration.

Such treatment improved only slightly the chill-proofness and stability of the beer, and was not a satisfactory solution. Important constituents were thereby removed from the beer, and the resulting product tasted empty and lacked foam-keeping quality.

I eventually found the solution of the problem. I discovered that, if a proteolytic enzyme—for instance, pepsin—or any other that is active in a slightly acid medium, is added to the beer, subsequent to the boiling of the wort, in extremely small quantities, it will render the beer chill-proof and stable.*

The small quantity of one gramme of pepsin added to one barrel of beer will accomplish this purpose. I also found that the addition of an excessive amount of pepsin will not alone fail to chill-proof the beer, but will make the beer even more sensitive to cold and unstable.

I have also found that the enzyme is not destroyed during pasteurization, but retains its activity. It is astounding that the presence even of such a minute amount as one part of pepsin in one million parts of beer can still be quantitatively determined by the edestin test.

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* U. S. Letters Patent Nos. 995,820 and 995,824.

The analysis given below shows the effect of proteolytic enzymes on the various nitrogen compounds contained in the beer. No. 1 represents the original beer, No. 2 the same beer after the enzyme action.

	I	II
Albumoses	27.0 per cent	10.5 per cent
Peptones	21.1 per cent	28.8 per cent
Non-precipitable	51.9 per cent	60.7 per cent

This method is now almost universally adopted in the manufacture of bottled beers in many countries, and the large majority of American breweries are using this process.

I have tried to point out the important part which the enzymes play in the fermentation industries, and hope I have succeeded in making clear at least the more striking phenomena. In a subject so vast and complex as that of enzyme action, one can only hope, in a paper of this size, to dwell upon the major workings, and I hope that it will not fail to contribute to a better understanding of the rôle of the enzymes generally, and particularly in relation to the fermentation industries.

THE PRODUCTION OF LIGHT BY ANIMALS.*

BY

ULRIC DAHLGREN,
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TUNICATES.

A large number of Tunicates have been announced as giving light, and among them are some of the longest-known and most classical examples of the power. Some of these forms are still in question, and further observation, followed by research, is desirable to determine the extent of the light-producing ability among the group. Among the animals in which the power to light is well known and in which it has been studied with care, one of the groups of Tunicates, the genus *Pyrosoma*, stands out prominently. So far as known, all the members of this genus are luminous to a powerful degree.

This animal lays fertile eggs in its brood pouch, and the egg develops into the primary individual, called the cyanthozoöid by Huxley. At about the time the egg or embryo is cast out into the sea to live its own life, this cyanthozoöid begins to give off buds, first two and then two more, making four. These buds grow into young, perfect individuals, and the budding goes on until a vast number have been formed, all still connected more or less, and lying in the same mass of tough, jelly-like substance, called tunicine, which is akin to chitin. In thus multiplying, the unit individuals become arranged to form an elongate cylinder of some few inches in length in the smaller species up to a number of feet long in the larger varieties.

Fig. 1 shows a photograph of the colony of *Pyrosoma elegans* from the Bay of Naples, Italy.

The cylinder has a central channel running from end to end of the colony and opening at both ends. The individuals that comprise the colony are placed in a radial position with their bases, on which the excurrent openings are found, forming the bounding wall of the central canal, while their distal ends, into which the incurrent channel of the individual opens, is directed outward, forming a more or less projecting papilla in every case. These papillæ are well seen in the photograph. Each papilla reaches out from an elongate structure which is still considerably thicker than the papilla, so that a shoulder is formed at the point of junction. The branchial region of the anterior part of the digestive tract which lies in the main body reaches about to this junction.

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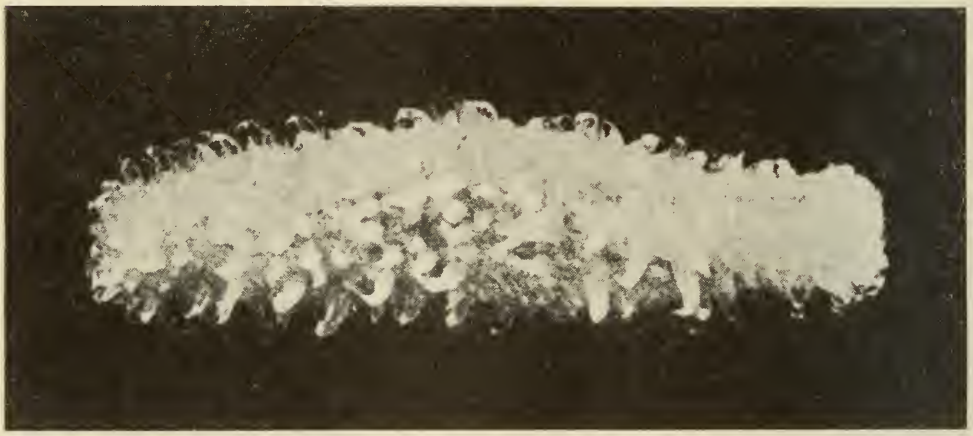
* Continued from page 624, vol. 183, May, 1917.

Panceri, in several able papers, studied the lighting of the animal and found that this light came, not from the whole body but from two medium-sized masses situated in the sides of the body just below the junction mentioned above (Fig. 2, *ol*). Examining the structures in both dark and daylight alternately several times, he found that these masses were those which had been incorrectly described by previous writers as ovaries, nephridia, lens-like bodies, and several other organs.

FIG. 1.

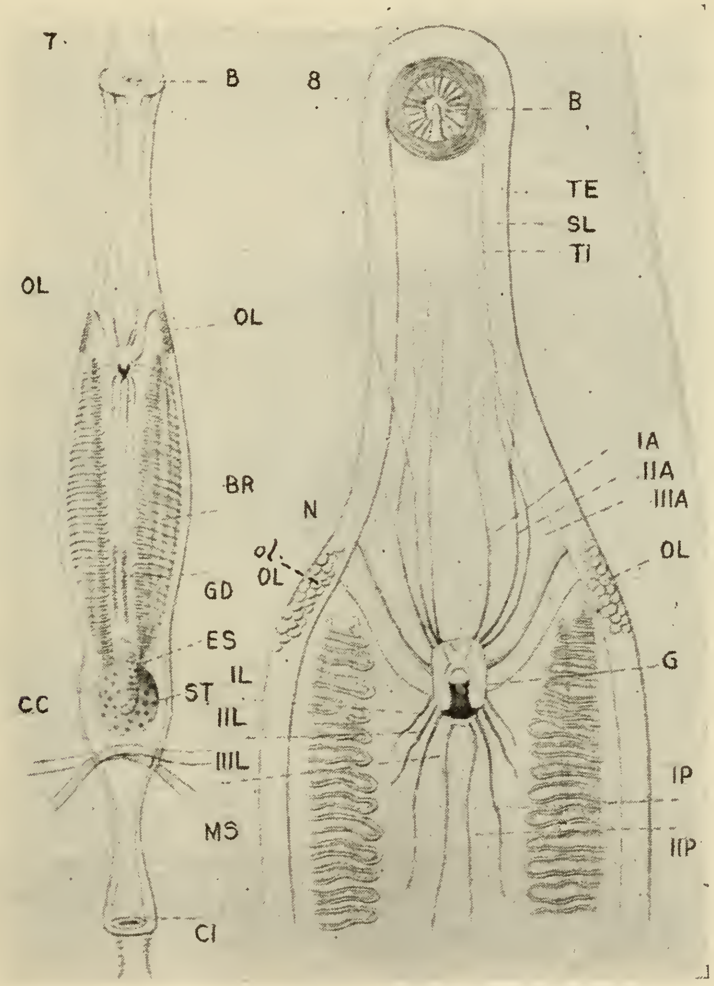


Photograph of an alcohol specimen of *Pyrosoma elegans*. (After Polimanti.)

He further found that the masses were cellular in nature, but incorrectly took them to be fatty bodies. They have also been studied and described since that time by several other investigators, with but little progress until the work was taken up by Julin at Naples and Villefranche and more modern methods employed.

The study of ascidian structure has shown us that its body is covered by the thick test, and that underneath that test, but not very intimately connected with it, lies the outer epithelial layer of the body. Most authorities agree that, contrary to our expectations, this test is not formed by the epithelium, but by certain mesodermal cells that have come through its surface and arranged themselves in various ways in the substance of the test. These cells are known as the "test-cells," and they have a peculiar and recognizable structure that has been well described by Julin and which is exhibited by Fig. 3, copied from Julin's work on the subject. These cells are called "internal follicular cells" by Kowalevsky and "Kalymnocytes" by Salensky.

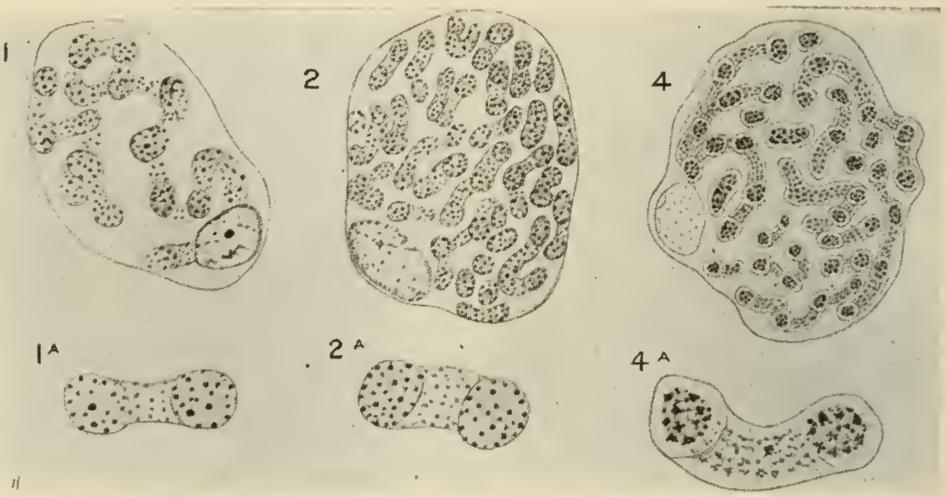
FIG. 2.



Drawings of two individuals of a colony of *Pyrosoma* (left-hand one on smaller scale). *Ol*, luminous cell-mass. (After Panceri.)

The test-cells lie in the test on the sides and ends of long channels which contain blood-vessels. Thus they are bathed by the blood stream and are in a position to show an active metabolism. Julin's chief contribution to our knowledge of the luminous organs of *Pyrosoma* consists in the discovery of the fact that the large cells that form the mass are modified test-cells lying in a space in the test that represents one of the enlarged blood-spaces known as the peripharyngeal blood-space. In the young egg and embryo all of the test-cells are light-giving, but in the young tetrazoid colony a portion of them, in the region mentioned, grow in size, become differentiated in structure slightly, and attain to the power of intensive lighting, while the remainder lose the lighting power and become useful only as formative elements of the substance of the test. They show fine streaming processes, passing into the test material, as in the case of cartilage, bone, and tooth-cells.

FIG. 3.



1 Test-cell of *Pyrosoma*. *1a*, enlarged portion of cytoplasmic inclusion; *2* and *4*, light-cells; *2a* and *4a*, portions of cytoplasmic inclusions (light-organs of cells). (After Julin.)

Julin has figured the adult light-cells, and his pictures are shown in Fig. 3, *2* and *4*. Here we see that it is a compact rounded cell of some size and that it shows a nucleus that is placed in some extreme side or corner of the cytoplasmic mass. In the majority of cases, especially in a young animal and with poor preparation, these cells show as small cells with a clear body and the nucleus placed over at one side. Panceri figures them thus, sometimes without even showing the nucleus. He took them to be fat-cells, and it is probably from observing these particular structures that he came to the erroneous conclusion that the light-producing substance was a fat.

Julin studied them in well-made preparations and shows (see his figures shown above) that the cytoplasm is filled by an elongate, spiral, and branching tube that simulates a branching nucleus, being bounded by a membrane and showing a reticulum. He describes granules of some material as clinging to this reticulum, and these we must assume for the present to be the granules of photogenin. The light-cells show this structure and its granules in common with the ordinary test-cells from which they are derived and which are all, during the younger embryonic stages, capable of lighting. By the time the embryo or larva is ready to be thrown off to pursue its independent existence, the general test-cells have lost the lighting power and only the specialized test-cells can shine. Fig. 3, 1, 1*a*, represents a test-cell and part of its reticular light-mass under higher magnification.

The blood supply of the light-organs has been accounted for: they lie bathed in the blood stream of the peripharyngeal sinus. As to a nerve supply, none has been demonstrated, and yet all experiments and observations show that they must be operated by nerve supply from the cerebral ganglion. The animal lights freely upon stimulation, and is said at times, when in its natural habitat, to shine continuously and with great brightness. In this case a natural and continual stimulus is evidently present. Peron in 1800, Bennett in 1833, and Meyen in 1850, recorded the presence of great masses of *Pyrosoma* on the high seas, giving off a great light by which one could see objects on shipboard.

Panceri studied the light in 1871 in several species. He records the color, from his own observations and from those of others, as clear blue in *Pyrosoma gigantum;* as varying from red to orange, pink, greenish, and, finally, blue in *Pyrosoma atlanticum.* He also made some long-extended studies of its powers of lighting and the conditions under which it is exerted. In the main the results of these experiments were correct, and much that we know was learned from them. In some cases, however, mistakes in the method resulted in erroneous conclusions.

Recent works by Oswald Polimanti and Fritz Burghause give us the best idea of the lighting processes of *Pyrosoma.* Polimanti worked at Naples on a suitable supply of living specimens of *Pyrosoma elegans* in the Naples Zoölogical Station. These specimens as found at Naples were from seven to ten centimetres long, although the species attains a length of over four metres in the Indian Ocean.

Pyrosoma, when brought into the laboratory and kept in a large tank of pure aërated sea-water of proper temperature (same as the sea temperature), lives well for some days and is normal in its reactions. It responds to many stimuli by exhibiting its beautiful light. This response is more full and intense than that of most other light-producing animals. When freshly dead or in process of ordinary dissolution it cannot be made to light, as is the case with some other animals, such as *Pennatula, Pholas,* or the *Lampyrids.* This appears to be due to the fact that the luciferine is not lasting or that it is freshly made for each exhibition, as in the ctenophores. On the other hand, that we are dealing with a substance that acts independently of any life-processes seems to be proved by the fact that the fresh living animals can be ground up or squeezed and the light material will then give a strong exhibition of light outside of the animal's body; also, by rapidly drying the substance, it can be preserved and later be made to give light by moistening it with fresh water or sea-water.

Polimanti states that at times the animal lights entirely spontaneously. This light may appear at only a few points, or the whole body may glow all over from the many points of light situated, two in the "shoulders" of each individual. Such a light well persist for a few seconds or minutes and then suddenly stop.

Panceri noted this fact and attempted to explain the communication of the lighting condition from one individual to others of the colony. He supposed that certain bands of muscle, common to the whole mass, did this in some way by their motion, but one can hardly accept this view of the case. We have seen in other forms that muscular action is entirely separate from the lighting power except as it acts indirectly by discharging the products or otherwise bringing them together, or as it results in forcing air or aërated blood into the light-tissues.

Some chemicals, as is often the case with other light-organisms, will cause the light to appear in *Pyrosoma.* They undoubtedly act on the creature's nervous system through pain, shock, or in some other pathological way, and cause the light to appear in this way. Fresh water is particularly favorable for this purpose. When placed in this medium the animal gives off a very bright, steady light for a long period, finally ceasing when it dies in its unusual surroundings. Ether and alcohol were applied by Polimanti and resulted in a very intensive lighting, which ceased at the end of from fifteen to twenty-five minutes. Whether this cessation was due to a narcotization of the central nervous system or to a more direct action on the nerve-endings or the light-cells themselves was not determined. When sulphuric acid in weak solutions was applied the animal died without giving off any light at all. We know that the light-processes will not take place in acid media, so it would appear that this acid quickly reached the light-cells and thus prevented the reaction. Further chemical experimentation could be profitably employed.

Mechanical stimulation was studied by Polimanti. He found that slight shocks, as rapping on the glass side of the aquarium, were enough to get a response by lighting; also, currents of water, produced by stirring when the animal was poked by a fine glass rod, caused it to light, but it was possible, if the action was gentle enough, to gently stroke its surfaces with the rod when no light appeared. Bubbles of air rising against it caused it to illuminate, and the presence of these bubbles in its cavities also did the same, although it reduced its sensitivity to other stimuli. The spread of the lighting from a point that had been mechanically stimulated was interesting. Polimanti found three cases: (1) If an animal was stimulated mechanically on one pole the light appeared first there, then on the opposite end or pole, and finally on the entire animal; (2) or the light spread out in bands like avalanches on the side of a mountain; (3) or the light appeared in a number of detached individuals and then in others until the whole colony lighted.

When the stimulation was applied to some middle point, much the same result was obtained. Sometimes the two ends lit first, or the light spread from the point stimulated; or it came, as in case three above, by detached points that increased in number until the whole animal glowed. Polimanti reasoned that a common nerve communication exists between the entire number of individuals in the colony, and that this communication acted in a manner that could be compared to the nervous correlation of a single organism.

The animals were then stimulated with an induction stream of electricity through platinum points. This gave results which much resembled the mechanical stimuli, except that it was modified by the distance that the actual stimulation extended into the tissues of the colony. Of most interest, however, were Polimanti's experiments with light as a stimulus. He used a small electric lamp of 32 candle-power and found that fresh, vigorous animals would respond to a flash from the light by a response of light from their own light-organs. We know at present of only one other form, the insects, where this is true, and in these it appears to be a mating adaptation. With weaker light-power it was hardly possible to get a definite response.

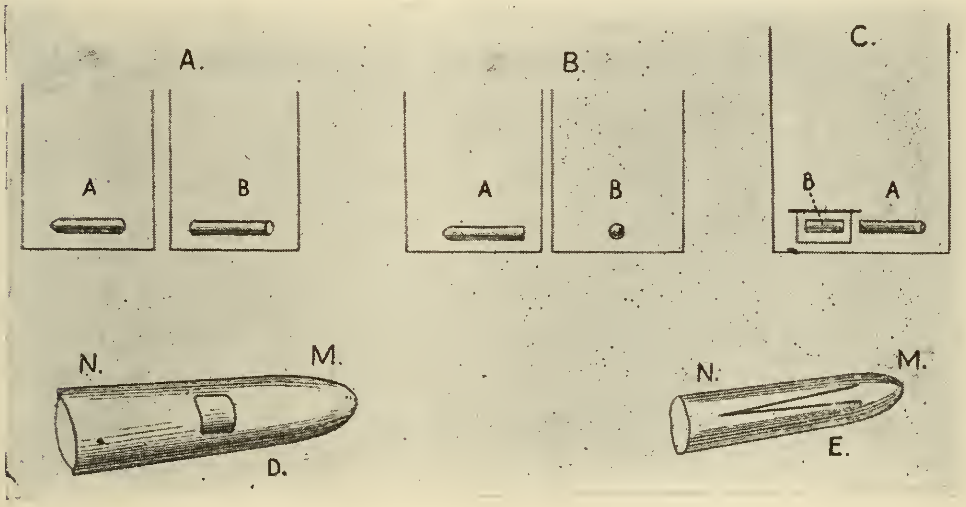
The light appeared on the colony in almost the same way as with mechanical stimulation. It might appear first at both poles and spread over the entire surface, or first at the surface and then deeper in the body. This latter condition probably means that the brighter glow brought out the inner tissues and organs, or it might mean that the adult individuals first lighted (their organs being farthest from the centre) and then the embryos which are near the inner surface of the cylinder. At times the animal failed to answer the light-stimulus, showing a varying sensitivity. We can thus see that the light-stimulation of the whole colony may result from the flash of one of its members or from the lighting of the members of another adjacent colony, or, in some cases, from the lighting of a totally different form, as a medusa or fish. This light-response was dependent upon a natural temperature and was confined to much narrower limits than in most other animals.

Burghause studied the light-emission in *Pyrosoma gigantum.* He found that the luminous organ-cells would not stain with Sudan III or osmic acid, thus demonstrating the absence of any fats. He failed to find the luciferine-luciferase reaction of Dubois, and even disclaimed the direct oxidation theory, because of his experiments with chloral hydrate and cyanogen compounds. He found the light confined to the light-organ, the ovary (eggs), and the buds and embryos. None was seen in the testis. He failed to find the varying light of several tints as described by

Peron, and ascribes it to pigments or foreign substances which might appear in the degenerating colony. All the light that he observed was of the greenish-blue color so characteristic of most luminous organisms. Also, he disagreed with Panceri and Polimanti as to the action of alcohol. When applied in strong concentrations the light was strongly shown at once. When gradually added in small quantities, however, it resulted in a narcotization under which it was impossible to get a light-response to any stimulation.

Burghause's most interesting observation was that, in fresh, vigorous colonies that were under normal temperature and in good sea-water, the light of one individual of the colony was answered by the lighting of those in its nearer neighborhood. He followed up this observation with careful experiments and drew a diagram (Fig. 4 in this article) to illustrate his results. In order to avoid stimulating the second colony (*b*) by accidental currents when the primary mechanical stimulus was applied to the first colony (*a*), the two were placed in separate jars or, as is seen in experiment (C), (*b*) was placed in a small dish in the same jar and covered with a glass plate to prevent disturbing it by currents produced when working with (*a*).

FIG. 4.



Diagrams of Burghause's experiments to prove response to light. For explanations see text. (After Burghause.)

In the first experiment (A) the colony (*a*) was caused to light. Shortly after it had done so the second colony (*b*) was seen to light first on the end nearest (*a*) and on those individuals which projected farthest out from the surface. The light then spread out over the entire colony. In experiment (B) (*a*) was stimulated and (*b*), whose longitudinal axis was now placed at right angles to that of (*a*), illuminated first on the side that was presented to (*a*) and then all over its surface. The strength of the reaction and its promptness was in a ratio to the nearness of the two colonies.

Burghause then tried the light of other animals; he used the ctenophores *Beroe ovata* and *Cestus veneris,* the siphonophores *Hippopodius luteus* and *Praya maxima,* as well as the Italian firefly *Luciola italica,* for the source of light, and found that *Pyrosoma* responded to them as well as to other light, although the intensity of their illumination fell far below the strength of 32 candle-power said to be necessary by Polimanti. They seemed to respond to this weaker animal light or even to a lighted match after they had ceased to respond on account of fatigue to mechanical or electrical stimuli. Bright daylight seemed to inhibit the process to some degree, in which *Pyrosoma* agrees with the ctenophores. The perception of light is evidently performed by the small pigmented organ lying on the main ganglion or brain of the animal. Since this is more easily reached by rays of light in the individuals which project farthest out from the colony, we can understand why these are the first to illuminate.

We can understand from the preceding accounts how the light may have some real use in the animal's life-habits. It would insure the closer approach of colonies that found themselves in the neighborhood of each other and consequently might insure the crossing of strains in their breeding. On the other hand, it must at times work against them by showing them to their enemies. The writer was told by Dr. L. R. Cary and others who had been studying marine animals in Bermuda that *Pyrosoma* is eaten by several large fishes of the grouper family in the deeper waters off that island. When these fishes were caught their stomachs were filled with large numbers of the colonies, presumably caught at night, as they had been partly digested when the fish were taken early in the morning. Polimanti knew this fact in Naples, and to test it he threw illuminated bits of *Pyrosoma* colonies into the fish-tanks and they were promptly eaten by the fishes. The pieces of illuminated flesh were also eagerly sought by crabs and other animals, which fought and sought to steal them from the fish that had already secured them.

A number of other Tunicates than the *Pyrosomas* have been observed to give light, among which may be mentioned: *Cyclosalpa pinnata, Salpa democratica, S. maxima* (appendiculata), *S. micronata, S. polycratica, S. cylindrical, S. socia, S. horneri, S. truncata, S. caudata, S. zonaria, S. tilesii, Phallusia intestinalis, Doliolum sp., Ciona intestinalis,* and *Botryllus schlosseri.* While most of these are undoubtedly accurately designated as light-bearing, the last two are very improbable cases and will doubtless prove to be lighted by some parasitic or commensal protozoa or other small organisms.

LUMINOSITY IN FISHES.

The great group of vertebrate animals shows light-production, so far as we know, only among the lowest of its five classes, the fishes. Three reports—one of a luminous porcupine from India by Morean, Schläpfer, and Thompson, in which the blood is said to be luminous; another by hearsay of many nonscientific observers that some herons and cranes show luminous patches under the wings; and a third by Brandes, Dobbs, Knaur, Killerman, Lindner, Purdy, Rey, de Sibour, Ternier, and Chun—have suggested that various owls and nest-young of certain finches have shown that the light is in each case either a delusion or that, if actually seen, it was an artifact or that it was due to the presence of luminous bacteria or fungi. Some of these reports still merit further investigation that will either prove or disprove them.

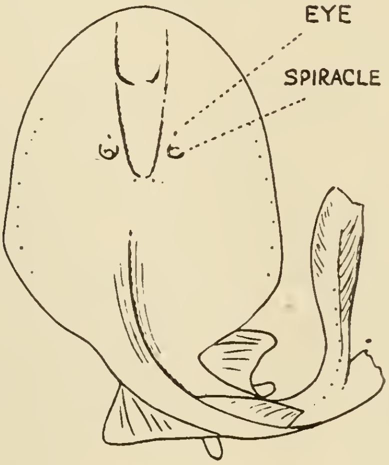
Of the light-producing power of many fishes, however, we can have no doubt, and the function is found among thousands of species—some selachian fishes and a more numerous assemblage of teleost fishes.

A current lay opinion on the subject ascribes all the luminous forms to those fishes which live in the abysmal depths of the ocean. While the greater number of them are so found, there are yet many others that live a pelagic life on or near the surface, and a still smaller number that lurk about the shores under stones or buried in mud or sand. Some spend most of their life in deeper waters and come on the coast to breed at certain seasons. All the luminous forms are confined to salt water.

Selachian Fishes.

These fishes present comparatively few light-bearing members. No skate or sting-ray has been found possessing light-organs. Of the torpedoes or electric rays one species has been reported, by word of mouth, by Dr. N. Annandale, of the Indian Museum at Bombay, and in his book on Indian seas, by Dr. Alfred William Alcock, as having a series of luminous spots on the outer edge of its disk. This fish is *Benthobatis moresii,* taken with the dredge in deep water off the Travancore coast, in water 430 fathoms deep. The fish has no eyes, and is the only animal so far known to possess both the power of producing light and the power of giving an electric shock. Fig. 5 shows a rough sketch of this form by Doctor Alcock. We have no knowledge of the structure of its luminous organs as yet.

FIG. 5.



Outline sketch of deep-water torpedo, *Benthobatis moresii*, from the Indian Ocean. The dots on the edge of the disk indicate the positions of the white spots that are said to be luminous organs by Alcock and Annandale. (After Alcock.)

The best-known group of Selachians are the sharks, and one order of these fish, the Cyclospondyli, have several members that show a very beautiful light. One of these, *Spinax niger*, is well known for its bright light, and is very common in deep tropical waters. The writer has specimens from Japan, and has seen it caught in the Mediterranean Sea at Naples, Italy.

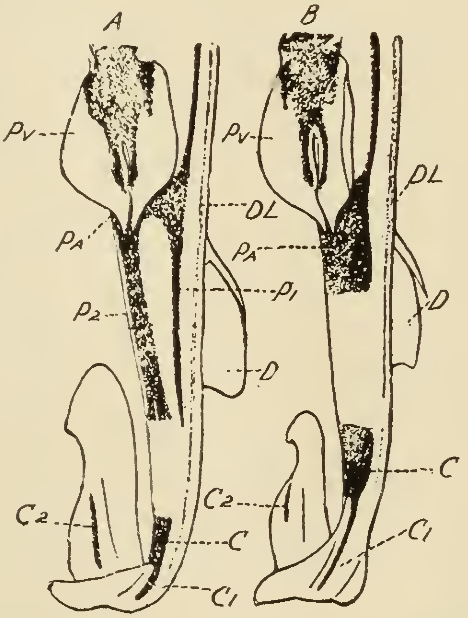
Several other allied, light-bearing forms are known. *Squalus fulgens and Leius ferox* have been reported to be luminous by Kuer in 1865. Rudolf Burkhardt examined a number of species of "deep-water dogfish" or "black dogfish" from Naples. He was given the opportunity of seeing them alive by Dr. Lo Bianco, of the Aquarium, and mentions, as luminous, *Læmargus rostratus, L. borealis, L. brevipinnis, Spinax pusillus, Sp. niger, Sp. granulosus, Enproctomicrus labordii, Centroscyllium granulosum, C. fabricii,* and *Paracentrosyllium ornatum.*

Dr. H. Oshima, of the Imperial University of Tokyo, has studied two interesting deep-water sharks of this group, *Etmopterus lucifera* and *E. frontimaculatus.* These two forms are very much alike, and, in regard to their luminous organs, almost identical, the only difference lying in a slightly varied arrangement of the numerous light-producing spots in their groups on the skin. Fig. 6 shows this arrangement, and we can also see that it closely resembles the pattern as seen in *Spinax niger.* Oshima's excellent description of their distribution reads as follows: ". . . In both species the punctate photophores are densely clustered in the following parts: small areas surrounding the nostrils, the ventral margin of the orbit, bases of paired fins, and, lastly, the postanal and caudal areas, with their extensions. In these areas there are to be counted as many as sixty or seventy photophores in a square millimetre of the skin, while in most other parts their number in an equal area does not exceed thirty or forty, and in still other parts where they are most scattered it sinks to ten or thereabout.

In these two fishes the light-organs appear as spots of a pearly lustre, and they can be easily counted and their distribution understood in the fresh specimen. In alcoholic and formalin specimens it is not so easy to see them, and they have lost their shining appearance, which is not due to their own light, but to daylight reflected from some internal surface. Under a low magnification, Oshima tells us, each organ is seen to be composed of a number of polygonal elements of a pearly lustre clustered together to form a rounded area and surrounded by a black ring of thickly accumulated pigment. In the adult specimen the smaller or punctate photophores are 0.10 to 0.15 mm. in diameter, while larger linear photophores are about 0.10 to 0.20 mm. wide and 0.30 to 1.35 mm. long. The linear photophores may be regarded as a series of punctate organs merged into one row.

Fig. 7 shows a section of one of the punctate organs taken through its vertical axis at its centre. Only certain cells of the organ appear here—the lens-cells (*L*) and the pigment-cells. The description of the light-cells and other structures of the similar organ of *Spinax niger* on a succeeding page will apply to this case also.

FIG. 6.

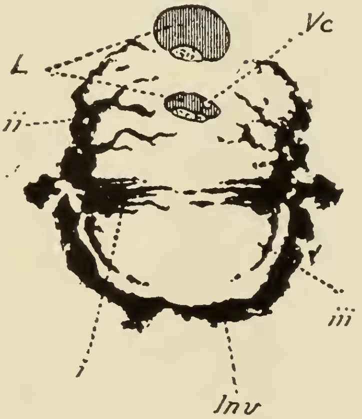


Posterior regions of the bodies of the deep-water luminous sharks, *Etmopterus lucifera* and *E. frontimaculatus*, to show the regions occupied by the light spots. These light-bearing areas are stippled in black. (After Oshima.)

Fig. 7 is drawn principally to show the form and discuss the probable use of the pigment-cells. In it we can note three kinds. Owing to the fact that no nuclei are seen and the cell outlines, where they touch, are invisible, we must explain that there are at least 10 or 12 separate pigment-cells represented in the black mass in the figure. The first sort are those below, and form a cup-shaped lower boundary of the proximal end of the organ (*INV*). This has been called the involucre of the organ. The light-cells rest in this cup, and it acts as a back-stop for internally directed rays and also possibly a reflector. Reaching inward from the rim of this are another series which may be termed the iris-cells. In the subsequent figure (Fig. 10) of the organ of *Spinax niger* this iris is represented as closed by the extension of these cells. We know that they do so move or that their pigment moves by streaming movements through the cytoplasm to get the same effect. The last of these pigment-cells are called by Oshima the " internal and external process " cells, and they are marked *ii* and *iii* in Fig. 7. Their exact meaning is difficult to determine, but they seem, especially the external processes, to be used to shade or direct the light toward the lens-cells.

Oshima found that the light was shown only on stimulation. When confined in an aquarium the fish swam about, but never lighted until seized and rubbed on the light-areas. The luminosity was pale (possibly owing to the capture and fatigue of the fish), and appeared slowly after some minutes. The light was local on the rubbed parts, and the writer agrees with Oshima that the stimulation does not get to the organ by means of nerves from the central nervous system, but that it is a direct result of the manipulation of the pigmented iris-cells. Possibly some more or less local plexus of sympathetic nerves has something to do with the matter. We must further learn if the light is more or less continuously produced by the light-cells and is only shown or hidden by the iris-cells.

FIG. 7.

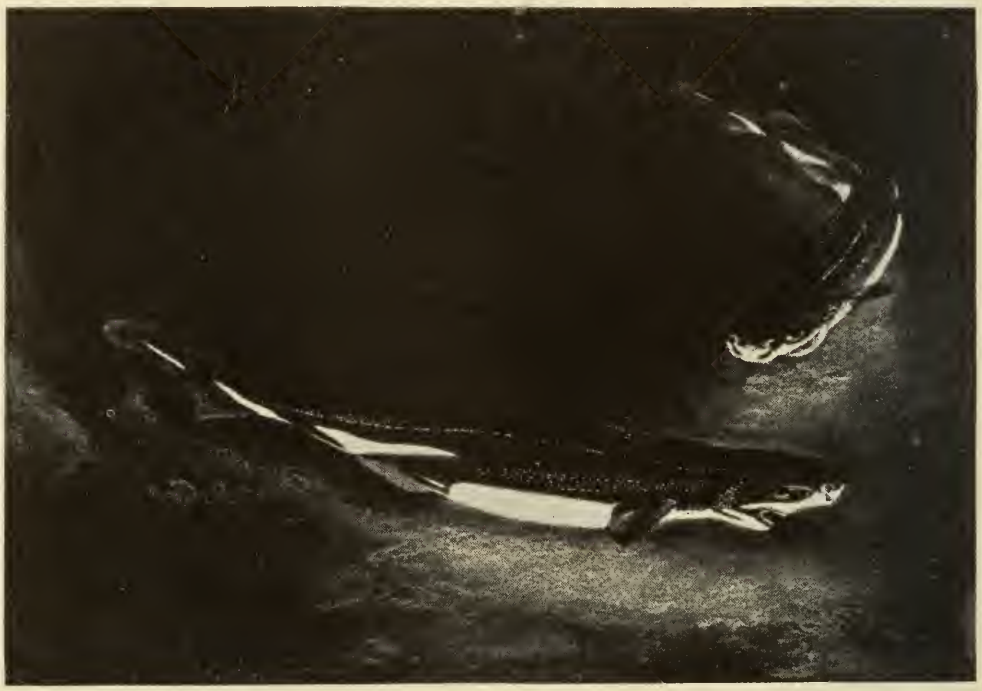


Vertical section through the long axis of one of the punctate light-organs of *Etmopterus*. *l*, lens-cells; *inv*, cup-shaped mass of reflector pigment-cells; *i*, iris pigment-cells; *ii*, external projecting pigment-cells; *iii*, internal projecting pigment cells. (After Oshima.)

It is to L. Johann that we owe the best study and description of this power in *Spinax niger* from Japan. This little shark is abundant in deep water in many seas. It is not more than two feet long and lives on a muddy bottom, where it feeds on small animals of all kinds. The fishermen of Japan and of Naples capture it on trawl lines baited with fish, squid, or other animal bait, and, in spite of the depth from which it is drawn, it is usually alive and can be placed in a tub of sea-water, where it swims about and, when stimulated by handling or otherwise, shows its bright bluish-green glow from many parts of the body.

Like most sharks the skin is covered by spiny points that give the rough feeling of shagreen. In this fish the color is very dark on the back, shading off to a brown on the ventral side. Cutting in on this brown are a number of splashes, stripes, and bands of almost black that take up a large portion of the under side of the head and belly in a characteristic pattern that is much the same in all specimens. When the living fish is stimulated in the dark these black areas give off a bright blue-green glow of the usual type found in light-giving organisms (see Fig. 8). The amount of light is in proportion to the freshness and vitality of the animal, and in good specimens is very bright.

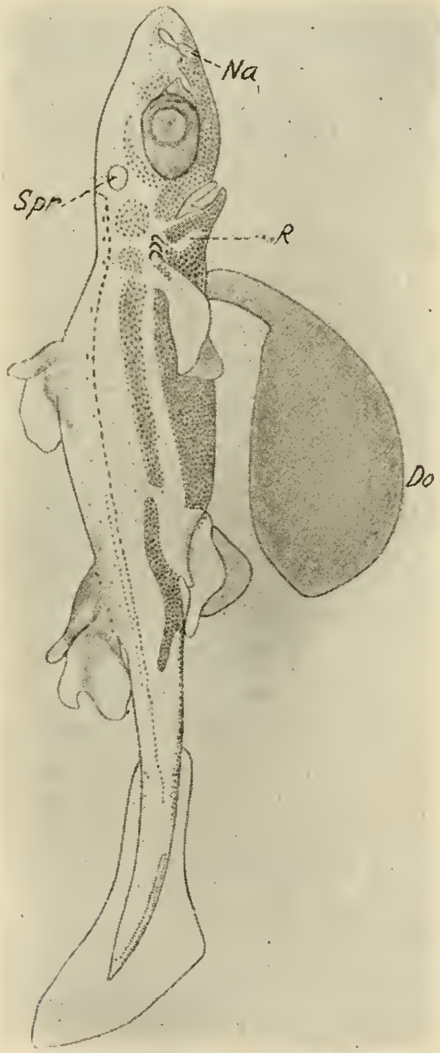
FIG. 8.



Drawing of two specimens of the deep-water shark, *Spinax niger*, with the light-areas in operation. (Drawn by Bruce Horsfall after descriptions by Johann, Beer, and the writer.)

The light does not shine all the time in captured specimens, and, presumably, not all the time in the animal when in its habitat. Of this latter point we are unable to judge, owing to the fact that the fishes live at so great a depth. It probably shines continually over long periods, however.

FIG. 9.



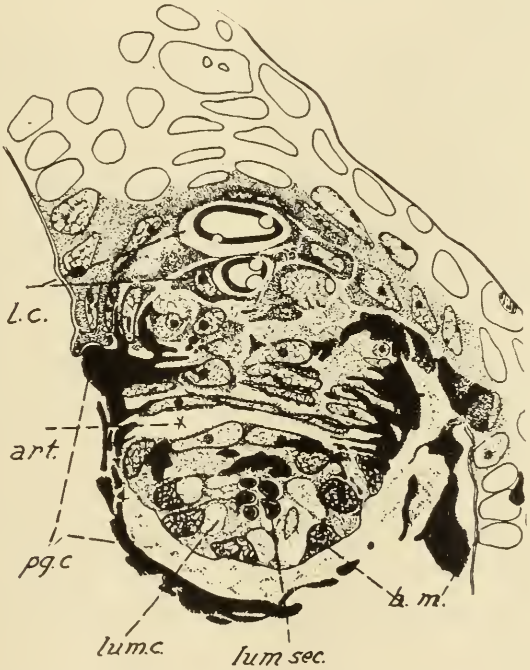
Line drawing of an embryo of *Spinax niger*, on which the grouping of the light-organs is shown by dots. (After Johann.)

When the fresh fish is examined with the naked eye in daylight or with a hand lens, one sees a large number of tiny black points very slightly raised from the skin. These occupy the dark areas before mentioned. Instead of following Johann's minute and accurate description of this distribution of these points (the light-organs), we will exhibit one of his figures of a young fish (see Fig. 9) on which are indicated by dotted areas the numerous patches of light-organs in the integument.

Johann further studied the microscopic structure of these organs and made out the chief points in their structure. Later Dahlgren and Kepner made a more careful study, and we will draw on this for our account. The minute organ is composed solely of modified regions of the stratified epithelium that covers the surface of the body in all fishes, the underlying connective tissues taking almost no part in its structure. In other numerous regions on the skin this same epithelium, in coöperation with mesodermal core, forms the tooth-like spines or scales. All pigment-cells in the epithelium—and they play an important part in the structure of the light-organs—are derived from certain amœboid, connective-tissue cells which secrete granules of melanin in their cytoplasm, as well as motor elements, and continue to possess the ability to move their melanin granules in such a way as to modify the light. It is probable that during growth and development the cytoplasmic bodies of these cells perform slow amœboid movements that bring them out of the mesoderm into the epithelium into such positions as we find them in the adult light-organs. Once in position, however, their chief movement is probably a temporary movement of the pigment granules inside the cytoplasm of the cells, in such a manner as to cause an apparent contraction or expansion of the cell, such as Spaeth has described for the epithelial pigment-cells of *Fundulus* and other teleosts. Thus the fish can shut off all or a part of its light. We need physiological studies on the lighting power of this animal.

All of the single light-organs of *Spinax* consist of a thickening and differentiation of small, round localities of its stratified epithelium. Sections show us (see Fig. 10) that this thickening is accommodated by a greater depression of the basement membrane at that point and a lesser raising of the outer surface of the body. The basal layer of cells is continued into the depressed cup of the basement membrane, with some interruption at the sides by the invading pigment-cells. On the bottom of the cup-like depression of the basal membrane a group of basal epithelial cells are differentiated to form the light-cells. Each one is elongate, has a wider base containing the large nucleus, and a distal end, somewhat narrowed by its position, in the tip of which is placed a single large granule of photogenin, the light-producing proteid. Owing to the concave surface on which these cells rest their tips come together in a spot of comparatively small area, and the granules of light-producing material thus occupy a small, definite area. Above the light-cells are found a few thin, laminated epithelial cells which appear to grow out from the sides of the cup and to be in touch with these sides from which they appear to grow.

FIG. 10.



Section of a single light-organ of *Spinax niger* through its long axis. *l. c.*, lens-cells; *art*, artifact; *pg. c.*, pigment-cells: *lum. c.*, luminous cells. (After Dahlgren and Kepner.)

Above them and apparently formed by their progressive proliferation are some thicker cells whose cytoplasmic bodies are filled with vacuoles. They seem to grade directly into a few larger cells on the top of the mass, in whose cytoplasm, instead of vacuoles, we find large single bodies of a depressed-oval shape. Their outer surface is formed by a thickened shell, inside of which appears a coagulum not shown in the figure. They are said by Johann to be transparent, refractive, and to constitute a group of irregular lenses to concentrate the light. Their nuclei are difficult to see, being flattened out in a side or corner of the cell. There are present in the average light-organ about a dozen light-cells and four or five lenses. The generalized outer layer of the stratified epithelium passes unbroken over the entire light-organ and raises some question as to the manner of its renewal. It undoubtedly is renewed by some of the laminated cells which pass through the vacuolated stage. It is possible, of course, that this does not happen and that they come entirely from the undifferentiated epithelium on each side of the organ. The latter hypothesis would relieve us of the problem of the fate of the lens-cells: whether they were permanent structures or if they slowly passed into the outer layer, to be cast off when they arrived at the surface.

The axis of the organ is seldom at right-angles to the body surface, and is usually inclined as seen in the figure. We have no record of the appearance of the light as seen with a low-powered lens in the living fish. This would give us an idea of the actual operation of the lens bodies; the light would appear at a number of quite different points if their refraction was good, while if not it would seem to come from duller spots of wider extent. The use of the function can only be guessed at. It is probably not used as a mating adaptation. In such a case it would be more concentrated in form and under more exact control.

As a means of illuminating the bottom and thereby showing the creature its prey it might very well serve. It would also do as a characteristic color marking to be used in the same way that fishes in shallower and lighter waters use their reflecting color patterns.

ADDRESS TO THE GRADUATING CLASS, THE FRANKLIN INSTITUTE, SCHOOL OF MECHANIC ARTS.*

BY

LOUIS EDWARD LEVY,

Vice-President of the Institute.

It is customary, when a class of students is about to be graduated from an institution of learning and its members are leaving to find their places in the world outside, for a speaker to address to the graduates some considerations of the purpose of their studies and some words to remind them that their efforts thus far have been only a preparation for the more strenuous tasks before them, when the knowledge they have acquired from teachers and from books is to be put to use in practical life and their mastery of their subject is to be adjudged, not in the estimates of teachers at the close of school terms, but tested by the value of their service every day, and in examinations more rigorous than any they had gone through in their school days. But the graduation of students from the night schools of the Franklin Institute presents conditions materially different from those which mark a similar occasion in the case of students who have for years been spending all their time in school or college and have thus, as yet, been students only. You members of this present graduating class, and, for that matter, you undergraduates as well, have not to be admonished of what you must expect to deal with in the workday world outside, for all of you are already active in that world and have here been devoting hours, after your daily tasks were done, in an earnest effort to more thoroughly equip yourselves for the work which you were yet to do.

You have here obtained a better understanding of the nature of that work and a fuller knowledge of the ways and means of accomplishing it. You have here learned the principles which are to be applied in your undertaking and have thereby gained a broader view of its meaning and a deeper insight into its purpose. As compared with students who pursue their courses under the seemingly more favorable conditions of uninterrupted study, you have had a great and valuable advantage in learning the science of your art in the light of your daily practice of it. There is more in this than would appear at first sight, the fact being that not only do the lessons thus learned become clearer to the learner, but also that his everyday experiences are in turn enlightened by his learning.

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* Delivered at the closing exercises of the Ninety-third Year of the School, April 20, 1917.

A course of education which adds to practical work a study of the principles on which its practice is based may well be regared as effective. And, inasmuch as your everday experience hereafter will constantly add to the practical part of your education, it is clear that to keep it effective the other part, in the form of further study, must be added by you as you go along. It is true, indeed, that our daily life is itself a process of education through the lessons of experience, and this is doubly true of those who have studied and continue to study how to better understand those lessons.

The effect of all education, as the word itself signifies, is to bring out from the inner consciousness of the learner his innate capacities of action; in short, as the saying goes, to bring out what is in him. But to bring out the best that is in him the teachings of experience alone are not enough. To that end there is need that the lessons learned through new experiences be combined with those of further study, for without that combination much that is in the learner will become useless through lack of development or worse than useless through a distorted development. It is as when a good planting, for want of cultivation, fails entirely or reaches only a stunted or defective growth. The idea suggested by Alexander Pope that "a little knowledge is a dangerous thing" but expresses in a terse formula the experience of every generation in every line of endeavor. You have doubtless already found out for yourselves that your studies here are only a beginning, and you will have to keep them up by yourselves if your mastery of your work is to keep pace with its requirements and your sense of proportion (that is to say, your judgment) is to be clarified by your experience.

It has often been remarked that the most that a school can do for its pupils is to teach them knowledge and the rules for applying it, but that the application of their knowledge to conditions which are exceptions to the rules can be learned only in the school of experience. But this is only a half-truth, the fact being that new rules are being made and old ones changed as science and the arts advance, and these advances must be kept up with after school days and study continue to go forward with experience. You have had the advantage of pursuing both courses together during the time of your schooling here, and the combined result of your daily experiences and your nightly studies has surely been your acquirement, however, unconsciously, of a capacity for a higher quality of service than could have been attained through either course alone. In all these respects you have but followed in the footsteps of many hundreds of your forerunners for whom the night schools of The Franklin Institute have opened the way to broader fields of endeavor and to larger spheres of usefulness.

Broad as those fields already are, broader than at any time before, they are daily being widened and their scope enlarged by the constant advances of science and the development of the arts. Every new achievement in these ranges of progress opens a vista of other and often greater possibilities beyond, visions which are yet to be realized by further effort directed by just such training as you have received here. There is no field of activity that cannot be enlarged, no addition to our knowledge of Nature's ways that does not offer to the worker an invitation to apply it. The field is open and the invitation is to you.

As I look back across the fifty years and more of my active experience I am impressed with a realizing sense of the fundamental changes which have been brought about within that time in all the various fields of human activity through the revelations of science which have so largely extended our control of the forces of Nature and so greatly widened the scope of the constructive arts. These developments have changed materially the conditions of our daily life, modified greatly our attitude towards surrounding nature, altered in many ways the interrelations of men and ultimately those of nations also. And now, within the short space of your schooling here, the world of human affairs has been going through a violent struggle in the process of its adjustment to these all-pervading changes, like as when an earthquake shakes the land in the course of adjustment to accumulated changes beneath the surface.

It is a struggle in which the course of civilization seems brought to a standstill and in which all the gains of science that make for progress and all the achievements of the arts that signalize it are being diverted from their beneficent purposes and applied to those of ruin and destruction on a scale of unparalleled magnitude. Of the authors of this terrible calamity, of the historic background of the struggle and of its political complications we need not here take account. More insistent, however, upon our immediate consideration is the fact that we here in this western world, where the adjustment of the social structure to changing conditions of life proceeds without violence as occasion for adjustment arises, we here, though far removed from the arena of the struggle and yet farther from its immediate causes, have been forced to take part in it and find ourselves at war. We are forced to take up arms in defence of those ideals of righteousness and freedom which have been the inspiration of our national life from its beginning, the upholding of which has given us leadership in the march of civilization, made our country a beacon-light for all the nations, and centred in it the hopes of all who yearn for righteousness and freedom throughout the world.

We are all of us called upon to stand together in this defence. We are each of us called upon to do our part in warding off the danger to our welfare and to join with all who in this great war are fighting to prevent the rule of might being made superior to the rule of right, and to put an end to the sway of force in the lands of civilization.

This great war is certain to be followed by a yet greater peace, when the disjointed remnants of the Dark Ages of Europe that yet clutter the roadway of the world's progress will have been swept away and the march of civilization, now so cruelly arrested, will be resumed. It is for you and such as you throughout the land to do your part in the conquering of that peace and in hastening the day when the present revel of destruction will be ended and when you and such as you will be called upon to do the work of reconstruction that is to follow.

NATIONAL RESEARCH COUNCIL.*

BASIS OF ORGANIZATION AND MEANS OF COÖPERATION WITH STATE COUNCILS OF DEFENSE.

One of the most striking results of the war is its demonstration of the importance of scientific research in strengthening the national defense. Soon after the opening of hostilities, England and France were faced with industrial and military demands soluble only in their research laboratories. Looking ahead, it was seen that the conclusion of peace would be followed by a trade war with Germany, in which no industry not perfected by scientific research could be expected to survive. As a consequence there arose through governmental action in England, France, Australia, New Zealand, and Canada a group of research organizations charged with the mobilization of scientific men and laboratories for the study of military and industrial problems. The value of their contributions to military practice has been recognized by the French Minister of War and by Sir Douglas Haig in his reports from the front. The success of their efforts to relieve industrial distress resulting from the stoppage of exclusively German products has greatly enhanced the appreciation of scientific research by British and French manufacturers. Thus the scientific methods which lie at the basis of Germany's military and industrial strength have been effectively adopted by the Governments and peoples of the Entente.

In April, 1916, soon after the attack on the *Sussex* and our consequent demands for the cessation of submarine warfare had developed a critical situation with Germany, the President requested the National Academy of Sciences to organize the scientific resources of the United States in the interest of national security and welfare. The request of the President called for immediate and vigorous action. He expressed the desire that the Academy should coördinate the scientific resources of the entire country and secure the coöperation of all agencies, governmental, educational, and industrial, in which research facilities are available.

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* Acting as the Department of Science and Research of the Council of National Defense. Communicated by Dr. George E. Hale, Chairman.

The National Research Council, comprising the chiefs of the technical bureaus of the army and navy, the heads of government bureaus engaged in scientific research, a group of investigators representing educational institutions and research foundations, and another group including representatives of industrial and engineering research, was accordingly constituted with the active coöperation of the leading national scientific and engineering societies. The representatives of the government were appointed by the President, who promised his cordial support and the coöperation of the government departments. Subsequently (February 28, 1917) the Council of National Defense adopted the following resolution:

> "*Resolved*, That the Council of National Defense, recognizing that the National Research Council, at the request of the President of the United States, has organized the scientific forces of the country in the interest of national defense and national welfare, requests that the National Research Council coöperate with it in matters pertaining to scientific research for national defense; and to this end the Council of National Defense suggests that the National Research Council appoint a committee of not more than three, at least one of whom shall be located in Washington, for the purpose of maintaining active relations with the Director of the Council of National Defense."

Since that time the National Research Council has acted as a department of the Council of National Defense, charged with the organization of scientific researches bearing on the national defense and on industries affected by the war.

WORK OF THE RESEARCH COUNCIL.

In times of peace the work of the Research Council involves the promotion of research in every department of pure and applied science. At present, however, the attention of the Council is concentrated on war problems, both military and industrial. Let us see how these are attacked.

The Military Committee consists of the Surgeon General of the Army, the Medical Director of the Navy, the Chiefs of Ordnance of the Army and Navy, the Chief Signal Officer of the Army, the Chief Naval Constructor, the Engineer-in-Chief of the Navy, and the Director of the Bureau of Mines, the Chief of the Weather Bureau, the Director of the Geological Survey, Mr. Howard Coffin of the Advisory Commission of the Council of National Defense, the Director of the Bureau of Standards (Secretary), and the Secretary of the Smithsonian Institution (Chairman). This committee formulates most of the military problems, designating in each case an officer in one of the technical bureaus of the army or navy who is familiar with the requirements and with whom the investigator engaged in the work may keep in touch. Dr. Robert A. Millikan, vice-chairman of the Council charged with the correlation of researches bearing on the national defense, then organizes the investigation by enlisting the services of one or more men especially qualified by experience and laboratory equipment. If, as is usually advisable, several research men attack the problem simultaneously, Doctor Millikan arranges for any desired coöperation between them. Freedom of initiative is encouraged, and any attempt at hampering control or interference with the freedom of action required for successful research is carefully avoided.

The above remarks relate more particularly to physical research, though Doctor Millikan's field of activity embraces a much wider range. Associated with him in Washington are Doctor Bogert, chairman of the Chemistry Committee; Doctor Vaughan, chairman of the Committee on Medicine and Hygiene; Doctor Durand, Vice-chairman of the Engineering Committee, and Doctor Mendenhall, Vice-chairman of the Physics Committee. These gentlemen, as well as the chairmen of the other committees of the Research Council, are constantly engaged in organizing researches in their respective fields, in coöperation with the Military Committee and with Doctor Millikan. In this way a most helpful and inspiring association of our individual investigators, our universities, our industries, and the various branches of our Federal Government, is being brought about—a coöperation which is of the utmost value to any country and which is vital to it in time of war.

It may be of interest here to give some illustrations of the ways in which the various committees are contributing to the national defense.

Mathematics (Dr. E. H. Moore, chairman) and

Astronomy (Dr. E. C. Pickering, chairman).

Hydrodynamical investigations bearing on ship design and improvement of aircraft. Statistical studies and computations required in any field. Optical devices for lookouts, to facilitate the detection of the periscopes of submarines.

Physics (Dr. R. A. Millikan, chairman).

Exhaustive study of devices for dealing with the problems of submarine warfare; range-finders of various types; devices for detecting invisible aircraft and sapping parties; improvements in wireless apparatus and other instruments used with aircraft; military photography.

Chemistry (Dr. Marston T. Bogert, chairman).

Generation, detection, and absorption of hydrogen, and problems incidental thereto; absorption of other gases, particularly noxious ones; fire extinguishers; prevention of corrosion and electrolytic action on the hulls of vessels; non-corrosive metals and alloys for a great variety of uses; balloon fabrics; fabrics for army slickers; bacteriological and biological stains; synthetic drugs; special reagents for investigators; new explosives; new sources of important products; utilization of wastes and by-products.

Botany (Dr. J. M. Coulter, chairman).

Organization of a botanical raw products clearing-house, to aid manufacturers needing raw products of a botanical nature, such as gums, oils, resins, fibres, wood, etc., to find either new geographical sources or new specific sources.

Geography (Dr. W. M. Davis, chairman).

Special maps for military purposes; instructions for the use of topographic maps; handbooks on military areas; physiographic features of the United States.

Geology (Dr. J. M. Clarke, chairman).

Camp sites; finding of water supply; materials for road building; topographic structure of military areas; supply of necessary minerals.

Medicine and Hygiene (Dr. Victor C. Vaughan, chairman) and *Physiology* (Dr. Walter B. Cannon, chairman).

Antitoxins and serums for diphtheria, tetanus, pneumonia, dysentery, and meningitis; intradermal method of vaccinating for smallpox; polyvalent vaccines for typhoid fever; sterilization of drinking water; toxicity of preserved foods; soldiers' clothing and blankets; infected wounds; shock; fatigue; occupational diseases, with special reference to munition workers; protection of the ear from high explosives; instruction of army and navy surgeons in the Carrel method of antiseptic surgery.

Anthropology (Dr. W. H. Holmes, chairman) and

Anatomy (Dr. H. H. Donaldson, chairman).

Physical and hygienic requirements of recruits for the army and navy; language requirements; condition of teeth; abnormalities; minimum height and weight; standardization of measurements; data and materials for scientific research.

Psychology (Dr. Robert M. Yerkes, chairman).

Organization of psychological tests for use in recruiting, to eliminate mental defectives and nervous types; selection of recruits especially adapted for aviation and other difficult tasks; study and treatment of returned soldiers, nervously or mentally affected; aid in re-education of partially incapacitated men; aid in deciding government liability and award of pensions.

Engineering (Mr. Gano Dunn, chairman; Dr. Durand, vice-chairman).

This committee, which will organize research in the various branches of engineering, has just been established with the co-operation of the national engineering societies.

In addition to the above general committees, the Research Council has a number of special committees dealing with important problems.

Nitrate Supply (Dr. Arthur A. Noyes, chairman).

This committee, which was appointed at the request of the Secretary of War, to consider the process to be used by the government in its plant for producing nitrates for explosives and fertilizers, has submitted a full report.

Noxious Gases (Mr. Van H. Manning, chairman).

This committee is making an exhaustive study of noxious gases used in warfare, and the various methods of protection against them.

Food (Dr. Alonzo Taylor, chairman).

This committee is working in coöperation with Mr. Hoover and with the Department of Agriculture.

An extensive investigation of the toxicity of preserved foods is also being conducted by Doctor Rosenau in consultation with an advisory committee named by the Research Council.

Optical Glass (Dr. Robert A. Millikan, chairman).

Through the coöperation of the Bureau of Standards and the Geophysical Laboratory of the Carnegie Institution of Washington with glass manufacturers, the problem of supplying optical glass for military purposes is well advanced toward solution.

Foreign Service Committee (Dr. Joseph S. Ames, chairman).

The first step in any work of research is to learn what has already been accomplished in the same field. Great progress has been made abroad since the beginning of the war by the scientific investigators of the allied countries. A committee has accordingly been sent to Europe to report from the front on scientific matters of every kind and to arrange for coöperation in the study of questions still underlying military and industrial problems. This committee includes two physicists, two chemists, one metallurgist, and two representatives of medicine and hygiene.

Committees of the Research Council not immediately engaged on national defense questions are those on the Promotion of Industrial Research (Dr. J. J. Carty, chairman) and on Zoology (Dr. Edwin G. Conklin, chairman). The Agriculture Committee (Dr. Raymond Pearl, chairman) is coöperating with the Department of Agriculture in the organization of research and the mobilization of the agricultural resources of the country.

CENSUS OF RESEARCH.

A national census of the research facilities of government bureaus, educational institutions, research foundations, and industrial research laboratories is being taken by the Research Council. The forms from educational institutions, which are coming in rapidly, contain much valuable information bearing on the solution of defense problems. Forms for other institutions are now being sent out.

The Committee on Research in Educational Institutions has recommended the formation of Research Committees in universities, colleges, schools of technology, and other educational institutions where research is conducted. The Research Committees already established by a large number of institutions in response to this request serve as local organizations which work in coöperation with the Research Council.

COÖPERATION WITH STATE COUNCILS OF DEFENSE.

The organization of the National Research Council is based upon the principle of broad and effective coöperation between the numerous research agencies of the United States and those of the allied countries. The Council is in reality a federation of research laboratories, working together toward a common end. At present its chief purpose is to assist in winning the war, both by the perfection of military devices and by the solution of industrial problems which the war has occasioned. But in the future, as already stated, it will devote its attention to the promotion of research in all branches of pure and applied science.

The organization of researches bearing on the national defense frequently involves the coöperative effort of many investigators residing in different states. Sometimes the joint action of an entire university laboratory, provided for through the assistance of the Research Council of the university in question, is essential to success. We have several researches in hand in which entire laboratories are taking part. More commonly, however, individual investigators known to be especially qualified are enlisted by the National Research Council from widely scattered institutions.

Such is the mode of procedure necessarily followed in the study of national problems. Local questions are constantly arising, however, which can be best solved through the efforts of local investigators familiar with the particular industries or resources involved, acting in coöperation with a national body in touch with researches in progress at home and abroad.

We accordingly suggest that the representatives of science and engineering, or the Research Committees appointed by State Councils of Defense for the purpose of promoting through scientific investigations the industrial and agricultural development of the several states, arrange for close coöperation with the National Research Council. In this way the research activities of the states may be coördinated with one another and with those of the national government, and the information secured by the National Research Council and by the separate state organizations may be rendered available for all.

Communications regarding the Research Council may be addressed to the Chairman at the Munsey Building, Washington, D. C.

WASHINGTON, May 1, 1917.

Speed Governors for Motor Trucks. ANON. (*Municipal Engineering,* vol. lii, No. 4, p. 187, April, 1917.)—Excessive speed has always been one of the drawbacks in the use of the modern motor car, and the attempt has been made in the past to regulate speed by legislation, imposing fines and even imprisonment for violations. The principal practical trouble has been with the driver. The want of dependability on the part of the driver was strikingly illustrated in the results of an investigation made by French artillery officers early in the present war. It was found that the maximum speed at which certain pieces of heavy artillery could be moved with safety on steel tires was eleven and one-half miles per hour. On a test run of two hundred miles over normal roads at an average of thirteen miles per hour, the gun was returned with practically nothing complete, and as a useful weapon the gun had been completely ruined. Orders were at once issued limiting the speed of these guns, yet it was found that the drivers of the trucks trailing them could not be relied upon to keep within the prescribed maximum, and guns were repeatedly found to have been seriously injured through hurried, though short, movements of position. The remedy adopted was the governor equipment of the trucks.

One of the taxicab companies of New York City is now considering the governor equipping of all its new cabs and limiting the speed to the prescribed maximum of the speed regulations of the city. Motor trucks, more particularly the heavier varieties, complicate the problem so far as road legislation is concerned, because comparatively slow speeds for heavy trucks destroy the roads much more rapidly than much higher speeds on pneumatic tires. The importance of the speed factor in road wear is perhaps not generally appreciated. Highway engineers say that road shock, or the hammer effect of the vehicle upon the road, increases as the weight times the speed, assuming otherwise like conditions. Heavy loads on narrow or hard tires propelled at high speeds develop strains for which the average road is not designed and cannot successfully carry. It would seem, therefore, that automatic speed controls, particularly for commercial vehicles, are becoming necessary, whether from the point of view of public safety, the protection of the roads, or the protection of the vehicles themselves.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

THE EFFUSION METHOD OF DETERMINING GAS DENSITY.[1]

By Junius David Edwards.

[ABSTRACT.]

The effusion method of determining gas density, which is based upon the fact that the times required for the escape of equal volumes of two gases under the same pressure through the same small orifice are approximately proportional to the square roots of the densities of the gases, was investigated in order to determine the accuracy of the method and its sources of error. In coöperation with a number of men employing this method in the natural gas industry, a series of experiments was made, using their apparatus under field conditions. It was found that results in error by more than 10 per cent. were not unusual.

The theory of the effusion process was studied in order to determine the influence of the numerous variables affecting the apparent specific gravity. The effect of differences in physical properties upon the relative rates of effusion of air and hydrogen, argon, methane, and carbon dioxide at different pressures was determined. A more detailed treatment of the theory in the light of these results will be given in another paper. The facts observed in this study, together with the observations made on the effect of the effusion pressure, the confining medium, and the shape and size of the orifice, have been used in determining the most favorable conditions of operation for this method.

It is very important that the orifice be of the proper size and shape. Recommendations have been made as to the most suitable type and form of apparatus for use and specifications given to guide in the construction of the orifice.

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* Communicated by the Director.

[1] Technologic Paper No. 94.

It has been shown that the apparent specific gravity as determined by this method can be varied within rather wide limits by changing the conditions. However, by the observance of certain precautions in the construction and use of apparatus, it is possible to secure results accurate to about 2 per cent. The greatest precision is obtained where the physical properties of the gas tested show the least difference from those of air. Some further increase in accuracy, and particularly in reliability, can be gained by standardizing the apparatus as recommended.

THE EMISSIVITY OF STRAIGHT AND HELICAL FILAMENTS OF TUNGSTEN.*

By W. W. Coblentz.

In the present investigation data are given on the radiation from the inside and the outside of the turn of a helically wound tungsten filament in an atmosphere of nitrogen.

The intensity of the radiation from within the turn of the helix is from 90 to 100 per cent. greater than from a similar area on the outside of the turn. This is accounted for on the basis of multiple reflection within the helix. This modifies the quality of the light so that it is redder than the light from the outside of the turn.

The observed infra-red measurements on the radiation from within the helix and the computed values (obtained on the basis of multiple reflection and the reflectivity of tungsten) are in close agreement, which is further evidence that the phenomenon is the result of multiple reflection.

Tests were made with a Nicol prism, which showed that the light from within the filament is highly polarized, indicating that the quality of the light is quite different from that of a black body. The infra-red energy measurements also indicate that the quality of the radiation emitted differs from that of a black body.

Computations of the radiation constant of tungsten indicate, as found in previous investigations, that the Wien equation is not applicable to the radiation from tungsten.

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* Scientific Paper No. 300.

There is no indication that the temperature within the helix is higher than on the outside of the turn. A difference in temperature of 200° would be required to account for the observed difference in brightness of 90 per cent.; whereas pyrometric, thermal conductivity, and other measurements place this temperature difference at less than 5°.

Although the quality of the radiation has been modified by multiple reflection within the helix, it is not sufficiently similar to that of black-body radiation to permit its use in exact temperature measurements by sighting an optical pyrometer within the turns of the helix.

AN ANEROID CALORIMETER FOR SPECIFIC AND LATENT HEATS.*

By Nathan S. Osborne.

[ABSTRACT.]

The principle of the unstirred or "aneroid" type of calorimeter has been embodied in an instrument especially designed for determinations of the specific heat and latent heat of several substances in general use as refrigerating media.

Heat developed electrically in a coil located in the central axis of the cylindrical shell comprising the calorimeter is distributed by conduction to the calorimeter and contents, whose initial and final temperatures when in thermal equilibrium are measured by a platinum resistance thermometer.

Heat from other sources is excluded by enveloping the calorimeter with a metal jacket separated from it by an air space and keeping this jacket during measurements at the same temperature as the calorimeter surface, using multiple thermocouples to indicate this equality.

The calorimeter is adapted for use between − 50° C. and + 50° C. and for pressures up to 70 atmospheres in experiments where the measured heat added is used either to change the temperature of the contents or to evaporate a portion of the contents withdrawn as superheated vapor; in the first case the

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* Scientific Paper No. 301.

specific heat and in the second the latent heat of vaporization being obtained when proper corrections are made. Such experiments are described in separate papers, this paper being devoted to the description of the instrument and its calibration.

Several features to which special attention has been given are:

1. Refinements to reduce errors in the evaluation of thermal leakage. These refinements include the following details:

(*a*) Location of the heater in the central axis of the calorimeter so that abrupt thermal irregularities produced by the heat developed therein may be subdued before affecting the surface.

(*b*) Distribution of metal connections between calorimeter and jacket in such a way that the lead conduction is unaffected by inequalities in the surface temperature of the calorimeter.

(*c*) Protection by means of superficial copper sheaths of the calorimeter surface from abrupt variations in temperature such as may occur within during calorimetric measurements.

(*d*) Method of indicating relative mean surface temperatures of calorimeter and jacket by means of multiple integrating thermocouples, which permits the evaluation of, and usually the annulment of, the thermal leakage.

2. Provision, by means of a system of radial metal vanes, for the distribution of heat throughout the contents.

3. Provision for insuring the dryness of vapor withdrawn by means of baffle plate system.

4. Installation in the calorimeter of a strain-free type of platinum resistance thermometer selected to give requisite accuracy.

5. Devices for rapid cooling of the calorimeter, consisting of a copper ring which can be moved within the jacket so as to thermally short-circuit the insulating air space and permit the escape of heat to the cooled jacket.

6. Thermo-regulated bath for keeping the temperature of the isothermal envelope or jacket always under control of the observer in order to avoid any unmeasured heat increments by thermal leakage.

Many other details are described which have a bearing on the convenience or accuracy in the use of the instrument.

The method of manipulation in making measurements of heat capacity is described and the results are given of an extended series of observations in the temperature range from – 50° C. to + 50° C. to determine the heat capacity of the empty calorimeter.

WAVE-LENGTHS OF THE STRONGER LINES IN THE HELIUM SPECTRUM.*

By Paul W. Merrill.

[ABSTRACT.]

WAVE-LENGTHS of 21 of the stronger helium lines have been carefully measured photographically by means of the Fabry and Perot type of interferometer, using several separations. Nine of the lines were compared directly with the standard cadmium line 6438.4696A, the remaining lines being referred to these. The accuracy attained is nearly 0.001A, so that the lines will become available as convenient standards for many purposes.

The fact is well known that the separation of the effective reflecting surfaces of the interferometer usually appears to be slightly different for different colors. The possibility is noted of eliminating the effect on measured wave-lengths by taking differences of orders and of thickness from large and small interferometers.

The Kayser and Runge formula for spectral series with constants derived from three consecutive lines will not reproduce accurately even the next member of any one of the six series.

THE RELATIVE SENSIBILITY OF THE AVERAGE EYE TO LIGHT OF DIFFERENT COLORS AND SOME PRACTICAL APPLICATIONS TO RADIATION PROBLEMS.†

By W. W. Coblentz and W. B. Emerson.

[ABSTRACT.]

IN the present investigation the methods are practically the same as used by previous experimenters. In the visual measurements the spectral light was compared with a standard white light by means of a flicker photometer and also an equality-of-brightness photometer. The source of white light was a standardized vacuum tungsten lamp. A cylindrical acetylene flame was used as a source of spectral light. The distribution of energy

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* Scientific Paper No. 302.

† Scientific Paper No. 303.

in the spectrum of the acetylene flame was determined with great care in view of the fact that the disagreement in previous work seemed to be due, in part, to uncertainties in radiometrically evaluating the light stimulus.

Visibility curves were obtained on 130 persons, of which number seven were known to be color-blind. The visibility curve of the average eye, using 125 observers, is wider than previously observed.

As was to be expected, the visibility curves of no two persons appear to be exactly alike. When a visibility curve does not coincide with the average there is usually a marked departure from the average visibility in a given spectral region. This gives rise to (1) wide visibility curves with the maximum shifted toward the red, *i.e.*, "red sensitive," (2) narrow curves with a sharp maximum in the green, and (3) curves with the maximum shifted toward the violet.

The data available indicate that 60 per cent. of the cases examined fall into three quite evenly divided groups (*i.e.*, 20 per cent. roughly estimated in each group) which are either (1) red sensitive, (2) blue sensitive, or (3) average. Similarly, 30 per cent. of the cases examined are quite evenly divided into three groups which fall below the average in either (1) the red, (2) in the blue, or (3) in both the red and the blue, thus giving rise to an apparently high sensibility in the green. One person in about twenty has a very wide visibility curve as compared with the average.

The point of maximum visibility is very different for different observers. The curve of average visibility, when corrected for selective transmission of the ocular media, including the yellow spot, is very symmetrical.

The complete paper gives a mathematical equation of the average visibility curve, and applications of these data to physical photometry. Further applications are given in a separate paper.

Calculations are given showing that the eye responds to light having an intensity less than 1×10^{-16} watt.

This paper gives also data on diffuse light in the spectroscope used, and a screen is described which transmits radiations proportional to the average eye.

NOTES FROM NELA RESEARCH LABORATORY.*

ON "STEREOSCOPIC" COLORS.

By M. Luckiesh.

On viewing colored objects in the same plane, such as printing in various colors in the projected image of a lantern slide, the different colors do not always appear to be in the same plane. The author has found persons who have observed this phenomenon, but has been unable to find any published data. This note describes some preliminary measurements of the magnitude of this "stereoscopic" effect. Two wooden boxes, each containing a tungsten lamp and equipped with an aperture covered with a diffusing glass, were arranged so that one was stationary and the other movable. Before the diffusing glass in one box were placed a red filter and an opaque card in which a letter X was cut. The other box was similarly fitted with a blue filter and diaphragm in which a letter E was cut. The height of the letters was 2.2 cm. and the width was 1.5 cm. In a dark room these two colored letters stood out in space, and it was possible, by moving one or the other, to make them appear in the same plane. In obtaining the data in the table the red X was moved. In most cases it was necessary to move it farther away than the blue E in order to make both appear in the same vertical plane perpendicular to the line of sight. These amounts are given in centimetres for total distances, which are given in metres. There is a general increase in these amounts with increasing total distance.

The values in the table which bear negative signs indicate that in these cases the red X had to be *nearer* the observer than the blue E in order to appear in the same plane. This complicates the explanation. Besides the data presented in the table, seven other observers have been examined at one distance and each stated that the red X appeared closer than the blue E when they actually were in the same plane. The observations represented only one series of ten settings at each distance, with the exception of the first two observers, on which two series were run.

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* Communicated by the Director.

Total distance in metres	2½ cm.	4 cm.	5 cm.	6 cm.	7¼ cm.
M. L.	2.8	16.0	24.6	39.8	57.7
H. K.	4.8	13.7	21.0	31.7	46.2
F. G.	1.6	5.3	7.6	5.3	12.5
P. H.	3.1	15.1	8.4	35.6	49.5
L. M.	2.6	4.5	13.4	14.4	18.3
E. K.	7.4	28.2	50.9	22.6	71.7
H. P.	5.1	2.4		23.2	17.4
L. C.	−0.4	−1.9	1.4	8.9	−2.7
G. H.	−7.4	−18.5	−34.0	−37.6	−49.7

The phenomenon is somewhat fluctuating, although by training and with standardized conditions fairly consistent results were obtained. Computations from the data by M. L. indicate that chromatic aberration in the eye could account for this phenomenon, but the negative values for the last two observers complicate this explanation. If the two letters are placed in the same plane they will not appear in the same plane, but by nearly closing the eyelids they appear to move into the same plane. Similarly when the two objects were placed so that they appeared in the same plane, on nearly closing the eyelids the red X appeared more nearly in its true position; that is, back of the blue E.

When two very small artificial pupils were placed respectively before each eye the blue E could be made to appear either behind or before the red X. It appeared to move to and fro very strikingly, as the two artificial pupils were moved laterally with respect to each other. It appears that, for those who normally see the red X behind the blue E, when the artificial pupils were moved closer together the blue E apparently moved forward and when the pupils were separated a trifle more the blue E moved backward. Through these small artificial pupils both images appeared in focus at all times, which was not true with the natural pupils. On turning the head, results somewhat similar to the foregoing were obtained.

Differences in relative brightness and shape of the colored characters seemed to influence the magnitude of the results somewhat, although the effect was never reversed. The effect could not be observed with certainty with one eye. Training in observing the phenomenon seemed to be important in obtaining consistent results, although the observers whose data are presented in the table had no experience in observing the phenomenon excepting the first observer in the list.

To explain the phenomenon with certainty much more work must be done, but there are indications that it may be explained eventually as due to the different refractive indices of the eye media for radiant energy of different wave-lengths. This may cause a displacement of the colored images which gives rise to the stereoscopic effect quite in the same manner as in ordinary vision. If this is the explanation, the differences between individuals shown in the table will likely be explained by differences in the shapes and relations of the various parts of the eye, such as curvatures, eccentricity of pupils, etc.

The Audubon (La.) Sugar School. C. E. COATES. (*The Journal of Industrial and Engineering Chemistry*, vol. 9, No. 4, p. 379, April, 1917.)—A little over a century ago, when sugar was first made from beets, the root was low in sucrose and the process gave a poor yield of an inferior grade of sugar, with almost valueless molasses. The chemist and agronomist, working together, slowly raised the sucrose content of the beet-root until it was more than doubled; the chemist and engineer, working together, slowly improved the processes until a good yield of sugar was turned out, practically pure, and both the molasses and all the other by-products became sources of profit and not of loss. In consequence the net cost of beet-sugar fell year by year until it became a serious competitor of cane-sugar, and finally it was offered at prices closely approaching the cost of cane-sugar production. The sugar planters of Louisiana, appreciating the increasing gravity of the situation, decided to meet the competition of beet-sugar by the same method that made competition possible. In the late eighties they called to Louisiana Dr. W. C. Stubbs and established, under his direction, the Sugar Experiment Station at Kenner, La., which was subsequently moved to Audubon Park, on the outskirts of New Orleans. This station was financed entirely by the planters of Louisiana. A complete sugar-house was erected on a scale large enough to give commercial results, and altogether perhaps $100,000 worth of equipment was obtained either by purchase or gift.

As soon as the work was fairly under way it became evident that there were many leaks in the sugar industry as carried on in Louisiana, and that these could be stopped by proper scientific control. But when the planters looked for chemists and engineers they were not to be obtained. Up to that time the cane-sugar industry throughout the whole world had been carried on largely by the rule of thumb. Few men scientifically trained were to be found outside of Europe. In 1890, therefore, at a meeting of the Sugar Planters' Association, it was decided to establish, in connection with the Sugar Experiment Station, a school for the training of experts in sugar work. This was placed under the direction of Doctor Stubbs and was opened in 1891 as the Audubon Sugar School. This appears to be the first instance in America in which any industry established both laboratories for the scientific investigation of its problems and a school for the college training of men to put the theory into practice. In 1896 the school was incorporated with the Louisiana State University, preserving the name by which it had become known. In 1908 it was reorganized as a college of the university.

Mother Maps of the Country. ANON. (*U. S. Geological Survey Press Bulletin,* No. 317, April, 1917.)—When it is proposed to prepare a map for any special purpose, the first thing that should be done is to find out whether the United States Geological Survey, of the Interior Department, has not already printed a topographic map of the region. The Survey's topographic map has been called the " mother map," and it is being supplied to an ever-widening circle of industrial and scientific agencies for practical use in the study of all sorts of problems and the execution of all sorts of projects. It is especially valuable in the solution of problems that require a study of the configuration of the country. In other words the topographic map is an engineering base map that is useful for both the simplest and the most complicated engineering problems.

A recent notice in one of the industrial journals called attention to the fact that in some counties where extensive systems of road construction are being planned maps have been *prepared* to accompany the specifications and the calls for bids so as to show the location of all material supplies available and all railroad connections. The Geological Survey's topographic map is the accurate base for such a map *already prepared* and contains far more of the information desired than any map that can be specially prepared for such a purpose, except at a cost that would be absolutely prohibitive. On the Survey's base map any special data can be readily platted. On this map could be shown in considerable detail the routes of proposed highways as well as the adjoining country, together with all routes of railroad, water, and overland transportation. The contractor could thus locate his materials, determine the best means of transportation, and make his estimates with greatly increased confidence as to their accuracy.

Cities, state organizations, official boards, contractors, and others are recognizing more and more the immense practical service and value of a ready-made map which shows not only every physical feature of the area it represents, but all the works of man.

NOTES FROM THE RESEARCH LABORATORY, EASTMAN KODAK COMPANY.*

THE PHOTOMICROGRAPHY OF PAPER STRUCTURE.[1]

[ABSTRACT]

In the study of the ultimate structure of paper much valuable information can be obtained by means of photomicrographs of cross-sections of the paper stock.

In the course of some recent work on the penetration of various materials into paper stocks it was found necessary to develop a technique for making sections of paper stocks as thin as 0.05 mm. The following method was adopted:

The particular type of microtome used is manufactured by the Spencer Lens Company, of Buffalo. The micrometer adjustment permits of sections from 0.001 to 0.05 mm. in thickness being made.

The paper of which a section is desired is mounted between two pieces of gelatine-coated film, ordinary kodak N. C. film being used, the gelatine being moistened to cause it to adhere to the paper. The paper held between the pieces of film is then placed between two pieces of moderately dry castile soap. This "sandwich" is then placed in the chuck of the microtome with the paper edge normal to the razor edge. The use of the gelatine is important, as it forms a firm but slightly resilient binder for the paper and prevents tearing of the surface fibres.

Sections are then cut in the usual manner and mounted on slides in Canada balsam diluted 1 to 3 in xylol.

In photographing such sections the best results are obtained by using orthochromatic plates with a yellow filter. In the present work Standard Orthonon plates were used with the Wratten "G" filter.

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* Communicated by the Director.

[1] Communication No. 49 from the Research Laboratory of the Eastman Kodak Company, published in *Journal of Industrial and Engineering Chemistry.*

Pyrometers—Past, Present, and Future. R. P. BROWN, before Steel Treating Research Club. (*The Iron Trade Review,* vol. lx, No. 12, p. 671, March 22, 1917.)—So far as we know, the ancients, who baked excellent bricks and forged iron in their crude way, made use of a form of pyrometer used to-day with ever-diminishing success—the eye. The operation of the first mechanical pyrometers depended upon the difference in expansion of iron and brass. An iron tube containing a brass rod projected into a furnace, and these were mechanically connected to a multiplying movement which caused a pointer to pass around a dial. Thirty or forty years ago the Siemens copper-ball water pyrometer was quite largely used. It is still used by armor-plate manufacturers, and an accuracy within about 25° F. is usually attained.

Present-day pyrometers are based upon the change of resistance of a standardized conductor or the change of the electromotive force from a thermocouple with a change of temperature. The resistance thermometer is an exceedingly accurate one, but is hardly to be recommended for high temperature service. For measuring temperatures above 1000° F. the thermo-electric method has come to be by far the most widely used. Experience has taught that for temperatures up to 200° F. a thermocouple of antimony and bismuth is best. For temperatures to 1000° F. a satisfactory thermocouple consists of one wire of iron, the other 60 per cent. nickel and 40 per cent. copper. For temperatures as high as 1800° F. one wire of 90 per cent. nickel and 10 per cent. chromium, the other wire 98 per cent. nickel and 2 per cent. aluminum, gives very satisfactory results. Either a millivoltmeter or a potentiometer is employed to measure the voltage produced by the thermocouple, the latter method being preferable where the greatest precision is required. In modern instruments provision is made for maintaining the cold junction of the thermocouple at a constant temperature.

The radiation pyrometer is a development of the thermoelectric pyrometer. Instead of placing the thermocouple inside the furnace where the temperature may be so high as to destroy it, it is placed in the back of a tube in front of a mirror. The rays of heat from the furnace enter the tube and strike the mirror, which brings them to a focus on the thermocouple. This instrument has a particular field for temperatures above 4800° F., and results with an error limit within 1 or 2 per cent. are secured.

If accurate results are to be secured from pyrometers, it is very essential that they be standardized at frequent intervals. The greatest future of pyrometry undoubtedly lies along the line of automatic temperature control, and great strides have been made in this country within the past few years in improving methods of heat treatment. Instruments which automatically control the temperature of electric furnaces have already been designed. These instruments maintain temperatures constant within 10° F.

NOTES FROM THE PHYSICAL LABORATORY OF THE UNITED GAS IMPROVEMENT COMPANY.*

EVIDENCE THAT PERSISTENCE OF VISION IS A PHYSICAL CONDUCTION PHENOMENON.

By Herbert E. Ives.

In developing a physical theory to explain persistence of vision and the behavior of the flicker photometer, Ives and Kingsbury [1] have made use of the Fourier conduction equation, thereby assuming that the necessary sluggishness of the visual apparatus is introduced by the transmitting medium, *e.g.*, the optic nerve, which would accordingly have the characteristics of a cable or telephone line of considerable length.

An alternative and perhaps simpler assumption would be that the inertia is a property of the surface at which the reaction due to light takes place, the effective length of the transmitting system being negligibly small, so that the reaction may be considered as being measured at the point of occurrence.

This condition may be expressed by the equation

$$I_0 = c\frac{d\Theta}{dt} + b\Theta \tag{1}$$

where I_0 = intensity of stimulus, *i.e.*, rate of reception of radiant energy.
t = time.
c = capacity of surface.
θ = quality (*e.g.*, temperature, potential, concentration, etc.).
b = coefficient of loss of energy, as by radiation or conduction.

If this surface receives radiant energy whose intensity varies in a periodic manner, as represented by the equation

$$I_0 = \frac{I_1}{2} + \frac{I_1}{2}\sin \omega t \quad \left(\begin{matrix}\omega = \text{angular speed} = 2\pi \times \text{frequency} \\ t = \text{time.}\end{matrix}\right) \tag{2}$$

the resultant reaction is given by the equation

$$\Theta = \frac{I_1}{2(b^2 + c^2\omega^2)}(b \sin \omega t - c\omega \cos \omega t) + \frac{I_1}{2b} + \left(\frac{I_1\omega c}{2(b^2 + c_2\omega^2)} - \frac{I}{2b}\right)e - \frac{bt}{c} \tag{3}$$

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* Communicated by the Chief Physicist.

[1] *Philosophical Magazine*, November, 1914, p. 708, and April, 1916, p. 290.

It is evident that if ω is made large enough a uniform effect is produced after the steady state is reached, proportional to $\frac{I_1}{2}$. This treatment is therefore satisfactory in so far as Talbot's law is concerned.

In order to choose between this treatment and the one involving the idea of conduction, it is necessary to study the speed of disappearance of flicker. An apparently crucial test is furnished by studying the critical speed for two dove-tailed sine-curve stimuli, I_1 and I_2. Introducing these in equation (3), it is found by differentiation that the range of amplitude of the reaction is

$$R = \frac{I_1 - I_2}{\sqrt{b^2 + c^2\omega^2}} \tag{4}$$

and the fraction this is of the mean amplitude is

$$\delta = \left(\frac{I_1 - I_2}{I_1 + I_2}\right)\frac{2b}{\sqrt{b^2 + c^2\omega^2}} \tag{5}$$

If we assume that the condition for disappearance of flicker is the constancy of δ we may solve for the critical speed, obtaining

$$\omega_c = \frac{2b}{c\delta}\sqrt{\left(\frac{I_1 - I_2}{I_1 + I_2}\right)^2 - \left(\frac{\delta}{2}\right)^2} \tag{6}$$

If ω is plotted against $I_1 - I_2$ for small values of δ, it is evident that the result is practically a straight line. Actually, as shown by experiment, the relationship is represented by a pronounced curve, to which fact is largely due the sensibility of the flicker photometer.

The equation similar to (6) which is derived from the conduction theory is

$$\omega_c = 2K\frac{\left(\log\frac{2}{\delta} + \log\frac{I_1 - I_2}{I_1 + I_2}\right)^2}{(x \log e)^2} \tag{7}$$

which represents the experimental facts excellently.

Other equations similar to (1) which have been suggested for visual processes and which do not take into account the effect of a transmitting medium appear to fail in the same way.

It thus appears that the damping effect to which persistence of vision is due is located in a conducting medium, which fact must be recognized in any theory of visual response.

THE COLOR TEMPERATURE OF ILLUMINATING GAS FLAMES.

By E. F. Kingsbury.

It is of considerable importance in the photometry of gas flames to know their color temperature, because it determines the efficiency at which incandescent electric lamps must run to match them in color.

While the color temperature of the ordinary illuminating gas flames has been known approximately for a long time, recently the question of its variability with the quality of gas and the flame size arose; so the following data may be of interest. Each flame was matched against a carbon lamp whose efficiency was accurately known at several voltages. Using the data on color temperature given by Hyde and Forsythe in the March INSTITUTE JOURNAL, these matching voltages have been evaluated in terms of temperatures:

Color Temperatures of Various Gas Flames.

Source	Lamp voltage (E. T. L. No. 4621)	Color temperature °K.
1. Coal gas, full flame	111.0	2075
2. Coal gas, half turned down	107.5	2035
3. Water gas, full flame	115.4	2118
4. Water gas, half turned down	105.5	2015
5. Water gas, full flame, edge on	111.5	2080
6. Mixed gas, full flame	113.5	2095
7. Coal gas, full flame	113.8	2100
8. Coal gas, candle-shaped flame, height of Hefner	97.0	1940
(Reference points)		
9. Pentane lamp	93.5	1914
10. 4.85 w.p.m.s.c.p. carbon	110.4	2070
11. 3.73 w.p.m.s.c.p. carbon	118.8	2153
12. Hefner	88.0	1875

Nos. 1 to 6 inclusive were using an 8-foot Von Schwarz excavated head lava tip; No. 7 was with an 8-foot Bray Union jet tip, and No. 8 was with a ⅛-inch open tube; Nos. 9 to 12 were taken as references from the paper referred to. The coal gas was 8 to 9 candle-power and 575 B. T. U.; the water gas 27.5 candle-power and 690 B. T. U., and the mixed gas, 25 candle-power and 665 B. T. U.

As is to be expected, the color temperature of a flame is within certain limits dependent upon its shape, size, position, and composition of the gas. It will also vary in different parts of the flame, the values given above being integral over the entire surface. It will be noted the full flames are slightly whiter than the ordinary 4 w. p. h. c. p. carbon standards. The color temperature of 1870 ° for the mixed gas flame given by Hyde and Forsythe in the paper referred to is considerably lower than any of the above values, which represent extremes in illuminating gas characteristics.

THE UNITED GAS IMPROVEMENT COMPANY,
PHYSICAL LABORATORY,
April 16, 1917.

Boron-Copper. ANON. (*La Chronique Industrielle,* vol. 40, No. 285, p. 2, March 16, 1917.)—Isolated for the first time by Moissan in 1895, and since several years made commercially available by the researches of Dr. Weintraud in the laboratory of the General Electric Company at West Lynn, Mass., boron possesses great affinity for certain substances to the exclusion of others. This property is particularly available in the refinement of copper in which dissolved gases, particularly oxygen, cause blowholes and porosity. In the past the elimination of these impurities has been effected by additions of magnesium or zinc, but these metals formed alloys with copper of inferior conductivity. Boron, however, has no affinity for copper and combines energetically with the oxygen, thus eliminating the gas and its effects.

As produced by the National Alloys Limited of Ilford (Essex), which has developed the product, boron-copper consists of electrolytic copper of the greatest purity. Impregnated with fluoride of boron in the gaseous state, the resulting product is employed as a deoxidizing agent in the production of various metals and alloys. Copper castings of exceptional soundness and electrical conductivity are obtained by the addition of 1 per cent. to 3 per cent. of boron-copper. Radiographic examination, recently introduced in metallurgical technology, shows a marked difference in microstructure between the metal treated with boron and the untreated metal, the boron metal being quite uniform, while the untreated metal, though of good quality, shows marked porosity. Boron-copper is equally applicable to all alloys of which copper is a constituent, from gold to steel, including the intermediate types, such as tin, zinc, nickel, lead, and aluminum. Alloyed with steel in the same manner as nickel, but using half the amount required of the latter, a steel substantially equal in quality to nickel-steel is obtained and at lower cost.

NOTES FROM RESEARCH DIVISION, ELECTRICAL ENGINEERING DEPARTMENT, MASSACHUSETTS INSTITUTE OF TECHNOLOGY.*

IMPROVEMENT IN HOT-WIRE ANEMOMETERS.

THE electrical hot-wire anemometer is based on the principle, discovered experimentally in 1909,[1] that a thin uniform wire, kept at constant resistance and temperature by an adjusted continuous electric current, and immersed in a uniform transverse wind, dissipates heat convectively in proportion to the temperature elevation of the wire above that of the passing air, and also in proportion to the square-root of the wind velocity. Experimental measurements of wind velocity employing this principle have been made by Kennelly and Sanborn,[2] by Morris,[3] and by L. V. King.[4] In these measurements the wind-measuring wire forms one branch of a Wheatstone or Kelvin electric bridge, and is kept at constant resistance, which means constant absolute temperature, while the electric power dissipated by the wire is observed. The total wind velocity (including the virtual velocity of free convection at rest) is then proportional to the square of the power per degree Centigrade temperature elevation, or

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* Communicated by the Director.

[1] "The Convection of Heat from Small Copper Wires," by A. E. Kennelly, C. A. Wright, and J. S. Van Bylevelt, *Trans. A. I. E. E.*, June, 1909, vol. 28, p. 363, part i.

[2] "The Influence of Atmospheric Pressure upon the Forced Thermal Convection from Small Electrically Heated Platinum Wires," by A. E. Kennelly and H. S. Sanborn, *Proc. Am. Phil. Soc.*, April, 1914.

[3] "The Electrical Measurement of Wind Velocity," by J. T. Morris, *The Electrician*, October 4, 1912, pp. 1056–1059.

"Distribution of Wind Velocity About a Circular Rod," by J. T. Morris, *Engineering*, vol. 96, pp. 178–181, August 8, 1913.

[4] "On the Convection of Heat from Small Cylinders in a Stream of Fluid," by Louis Vessot King, *Proc. Royal Society*, vol. 90, May 5, 1914.

"On the Precision Measurement of Air Velocity by Means of the Linear Hot-wire Anemometer," by Louis Vessot King, *Phil. Mag.*, vol. 29, April, 1915.

"The Linear Hot-wire Anemometer and Its Application in Technical Physics," by Louis Vessot King, JOURNAL OF THE FRANKLIN INSTITUTE, January, 1916.

$$V = \frac{1}{k'p}\left(\frac{P_e}{\theta}\right)^2 \qquad \text{cm./sec.} \qquad (1)$$

where p' is the atmospheric pressure (bars)
P_e is the linear dissipation (abwatts/cm.)
θ is the temperature elevation (deg. C.)
k' is a constant depending on the surface condition.

It is evident that if the temperature of the moving air changes during the test the apparent total wind velocity at constant resistance of the test wire will also be changed. If the working temperature of the test wire is kept high, changes in the ambient temperature will have relatively small effects; but if the test wire is operated at, say, 50° C., while the ambient temperature of the air in the wind is at 20° C., a small change in the ambient temperature will affect the deduced wind velocity V materially.

A compact form of Wheatstone bridge *ABCD,* used by Morris, had two arms, *AB* and *CD*, of platinum test-wire, and the other two, *BC* and *AD,* of Ia-Ia constant-resistance wire. Exposing all four wires to the wind, a Wheatstone bridge served to keep the tungsten wires at such temperature as made their resistances equal to those of the Ia-Ia wires.

Mr. Richard D. Fay, in a thesis towards the S.B. degree at the Massachusetts Institute of Technology this year, shows that the Morris bridge is essentially uncompensated for changes in ambient temperature, and that the observations must be corrected for such changes in order to arrive, by formula (1), at the total wind velocity. This difficulty can be overcome and an automatic compensation arrived at by making all four arms of the bridge of either tungsten or nickel wire. The two arms previously of Ia-Ia wire are now each made of two parallel tungsten wires, so that a bridge *ABCD* will have one wire from *A* to *B*, two from *A* to *D,* one from *B* to *C,* and two from *D* to *C.* The doubled wires are longer than the single wires in a ratio a of, say, about 2.5.

Under these conditions it will be found that if the same wind velocity acts constantly upon all six wires, if the ambient temperature changes, the bridge balance will be affected in such a manner that when balance is restored the total velocity is again proportional to the square of the power. In other words, the linear dissipated power P_c in (1) keeps automatically in direct relation to the temperature elevation θ when the bridge is kept balanced. A given set of six wires in constant surface condition thus requires a definite and constant temperature elevation for resistance balance under all ambient temperatures.

The advantage of this plan is not only that the observed wind velocities require no correction for ambient temperature, but also that low temperature elevations may be used. The test-wire device, in the most satisfactory form tried, had six fine nickel wires (diameter 0.155 mm.) mounted insulated in a sort of cobweb across a light brass circular frame 15 cm. in diameter. This frame was fastened to a handle, with the bridge wires leading over it to the battery, controlling rheostat, ammeter, and balance galvanometer. The nickel wire used had inferred absolute zero resistivity at – 233.6° C., and the length ratio $a = 2.083$. The temperature elevation θ was only about 15° C., and the wires did not become dangerously overheated if the bridge was balanced at a wind velocity of 18 metres per second (40 miles per hour) and then laid on table or removed from the wind. The wind velocities are proportional to the fourth powers of the total current supplied to the bridge for balance, this current varying from 0.74 ampère in still air to 2.18 ampères in air moving at 17.5 m./sec. (39 miles per hour). Calibration in a wind tunnel indicated a good straight-line law, on logarithm paper, between currents and actual wind velocities. This new automatic compensation principle promises to be useful in anemometry.

Exposure and Size of Plate in Wide-angle Photographs. ANON. (*British Journal of Photography,* vol. lxiv, No. 2972, p. 202, April 20, 1917.)—In the general case of wide-angle views, it is well known that an exposure just sufficient for the centre of the plate will be altogether inadequate at the corners. The falling off of the illumination at the corners is, of course, influenced very largely by the cutting-off effect of the lens mount when the aperture is over a certain size, therefore for high-speed work at large aperture we need a lens giving a fairly wide angle of full illumination. The mount nearly always cuts off some light, but by stopping down the aperture we can increase the angle of full illumination very materially and so avoid any interference by the mount up to very large angles. In that case the uncertain effect of the mount is eliminated, the illumination of the plate varies according to a definite rule, and it becomes possible to calculate the difference in exposure required, as the distance from the centre of the plate increases.

According to the rule given by Doctor Zschakke, the light entering the emulsion at any point on the plate is proportional to the fourth power of the cosine of the angle of obliquity of the light pencil, so that if this angle is θ, the light everywhere is proportional to $\cos^4$. We can then use this rule to determine the relative exposures at the corners and at the centre of the plate when a sufficiently small stop is used to make the angle of full illumination cover the whole plate. Taking an angle of 90 degrees, for example, with which the diagonal of the plate must be twice the focal length, the corners require four times the exposure necessary at the centre. With an angle of 105 degrees the corners require seven times the exposure at the center. With extreme wide angles this must always be the difficulty. Hence the origin of various patent lenses with revolving star stops, etc., designed to cut down the light in the centre of the plate.

Use of a Mirror in Portraiture. A. F. CATHARINE. (*British Journal of Photography,* vol. lxiv, No. 2973, p. 217, April 27, 1917.) —There is nothing original or new in the idea of making a photograph of a reflection in a mirror, but it is a useful expedient that does not seem to have been often employed. When the space available is too small to permit the use of a long focus lens, by introducing a mirror a viewpoint in effect is obtained beyond the wall of the room. The camera and sitter may be placed close together, with the mirror facing some point between them. The exterior focal distance is then the sum of the distances of the mirror from camera and sitter.

The negative naturally is a reversed one, and is only suitable for printing direct in single-transfer carbon, unless films are used which can be printed from either side. If the negative is for enlargement, the reversal is of no consequence, as it need be merely turned around in the carrier. By employing a lens with a slight amount of spherical aberration a most pleasing and even softness of definition is secured. Probably this is due to the fusion of the main and secondary images respectively reflected from the back and front of the glass. It gives to the image a certain luminosity of a somewhat similar character to a direct print from a negative made with a soft-focus lens. The texture of the image is not destroyed or even impaired, but there is a slight blurring outward from the *high-lights.* This gives an entirely different effect from that obtained in a direct bromide enlargement with layers of tulle on the projection lens, which produce an outward blurring from the *shadows.*

THE FRANKLIN INSTITUTE

(*Proceedings of the Stated Meeting held Wednesday, May 16, 1917.*)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, May 16, 1917.

PRESIDENT DR. WALTON CLARK *in the Chair.*

Additions to membership since last report, 5.

The Chairman announced that the business of the meeting would be the annual presentation of the Franklin Medal, the Institute's highest award, in recognition of distinguished scientific and technical achievements, and called upon Dr. Harry F. Keller, who gave an account of the work of Dr. Hendrik Antoon Lorentz, of the University of Leiden, recently recommended by the Institute's Committee on Science and the Arts for the Franklin Medal in recognition of "His researches which have so largely contributed to laying on a new foundation our knowledge of the nature of light and in developing our ideas concerning the ultimate constitution of matter."

Doctor Keller then presented His Excellency, Chevalier W. L. F. C. van Rappard, Ambassador of the Royal Netherlands Government to the United States, who received the medal for Doctor Lorentz, and conveyed the thanks of his Government and of the recipient for the honor conferred upon him.

Doctor Keller then introduced Admiral David Watson Taylor, U. S. Navy, who had also been recommended for the award of the Franklin Medal in recognition of "His fundamental contributions to the theory of ship resistance and screw propulsion, and of his signal success in the application of correct theory to the practical design of varied types of war vessels in the United States Navy."

The Chairman presented the medal to Admiral Taylor, who expressed his thanks for the honor conferred upon him and then read his paper on "The Science of Naval Architecture." He gave an outline of the progress in ship design and shipbuilding, and pointed out the dependence of naval architecture on the various other sciences, including mathematics, astronomy, chemistry, physics, physiology, medicine, and hygiene. Reference was made to the increase in the size of ships, their strength and stability, and consideration was also given to the question of resistance and the results of experiments conducted in the model basin.

Adjourned.

R. B. OWENS,
Secretary.

(A full account of the meeting will appear in the next issue.)

COMMITTEE ON SCIENCE AND THE ARTS.

(*Abstract of Proceedings of the Stated Meeting held Wednesday, May 2, 1917.*)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, May 2, 1917.

MR. WM. CHATTIN WETHERILL *in the Chair.*

The following reports were presented for first reading:

No. 2671.—Stellite. Advisory.

No. 2685.—Beach Reclamation Works. Advisory.

The following report was presented for reconsideration and adopted:

No. 2682.—Hooven Automatic Typewriter. Thomas A. McCall and John H. Pillings recommended to the City of Philadelphia for John Scott Legacy Medals and Premiums for their inventions embodied in this machine. The Edward Longstreth Medal of Merit awarded to the Hooven, Owens, Rentschler Company for the development of means of manufacturing this typewriter.

The following reports were presented for final action:

No. 2683.—Yeomans Method of Machine Construction. Lucien I. Yeomans recommended to the City of Philadelphia for the John Scott Legacy Medal and Premium.

No. 2687.—Portable Brinell Hardness Tester. Report referred back to Subcommittee for further consideration.

R. B. OWENS,
Secretary.

SECTIONS.

Sections of Physics and Chemistry.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, April 26, 1917, at eight o'clock, with Dr. George A. Hoadley in the chair. The minutes of the previous meeting were read and approved.

George E. Hale, Ph. D., Sc. D., LL. D., F. R S., Director of the Mount Wilson Solar Observatory, Pasadena, Calif., delivered an illustrated lecture on "Whirlwinds and Sunspots." A description was given of whirling storms in the earth's atmosphere (cyclones, tornadoes, and waterspouts), and of analogous solar storms, as shown by the study of the sun's upper atmosphere by means of the spectroheliograph, and by the spectrographic study of sun-spots. The magnetic phenomena associated with solar vortices and their bearing on the nature of sun-spots were also discussed.

The paper was discussed, a vote of thanks was extended to Doctor Hale, and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(*Stated Meeting, Board of Managers, May* 9, 1917.)

RESIDENT.

MR. EBER W. FINKBINER, Representative, E. F. Houghton & Co., and for mail, 5219 Columbia Avenue, Philadelphia, Pa.

DR. ANNABELLA E. RICHARDS, Demonstrator of Chemistry, Women's Medical College of Philadelphia, and for mail, Merion, Pa.

ASSOCIATE.

MR. GORDON MEADE ATHEROLT, Engineer, Atlantic Refining Company, and for mail, 1723 North Twenty-eighth Street, Philadelphia, Pa.

MR. ALBERT DE MACEDO, Mechanical Engineer, Midvale Steel Company, and for mail, 3925 Poplar Street, Philadelphia, Pa.

MR. BERNARD L. DOUREDOURE, Student, 103 Walnut Street, Philadelphia, Pa.

CHANGES OF ADDRESS.

MR. ANDREW ALLAN, JR. Harrison, N. J.

MR. C. W. BARWIS, care of Pennsylvania Railroad Company, Wilmington, Del.

MR. M. D. BURKE, R. F. D. No. 8, Ashland, Ohio.

MR. R. G. COOLBAUGH, care of Camden Forge Company, Camden, N. J.

MR. JOHN P. EATON, 1373 Narragansett Street, Philadelphia, Pa.

MR. EDWIN ELLIOT, 250 West Johnson Street, Germantown, Philadelphia, Pa.

MR. JAMES GAYLEY, 555 Park Avenue, New York City, N. Y.

MR. J. ROGERS HOLCOMB, Walnut Hill, New Castle, Del.

MR. TINIUS OLSEN, The Gladstone, Eleventh and Pine Streets, Philadelphia, Pa.

MR. LAWRENCE T. PAUL, 118 Mill Street, Newport, R. I.

MR. A. B. STITZER, care of Republic Railway and Light Company, 60 Broadway, New York City, N. Y.

MR. HARRISON D. STRATTON, 1007 Irwin Avenue, Pittsburgh, Pa.

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BOOK NOTICES.

LAWS OF PHYSICAL SCIENCE: A REFERENCE BOOK, by Edwin F. Northrup, Ph.D. Philadelphia, J. B. Lippincott Company, 1917. 210 pages, 12mo. Price, $2.

The purpose of this book may be inferred from the following paragraph in the preface: "The *data* of physical science are readily accessible in several published tables of physical constants. The *mathematics* used in physical science has been summarized, classified, and formulated for ready reference in many published books. The author is not aware, however, of any handbook or reference work which contains a full list of the *general propositions* or *laws of science*."

The reviewer thought to test the volume and so wrote down a score of topics which might come under the general purpose of the book, and the book stood the test well. Ohm's law for electric currents happens to have been omitted from the index, but is found in the text. Poisson's ratio, the Stark (Lo Surdo) effect, and series of spectral lines were not found, but in strictness these are not "general propositions or laws of science," and the author must draw a line somewhere.

In all, about six hundred topics are treated, and well treated. References are given to more extended discussions of each topic, and a bibliography tells us just what edition of a book is referred to. In this connection one wonders sometimes why so ancient an edition is cited. It is interesting to note that all the books referred to are written in either French or English, with the exception of just one in the language of our enemy.

The book before us has so high a value and is so likely to be revised that the author will pardon a suggestion or two for the second edition. Would it not add to the value to refer in each case to the original paper as well as to subsequent treatments? Further, the index should be made more ample, since it is by thumbing it that the approach to the book will be made. Some topics should be otherwise located. Curie's Law of Magnetic Susceptibility should be classified with Magnetism and not in its present position under Heat and Physical Chemistry.

The reviewer finds he has spent some words in apparent disparagement. Did he not regard the book as useful and valuable he would not have wasted time in making suggestions. His opinion is that Doctor Northrup has done a needed piece of work very well indeed. He has given the physicist a good additional tool, and every one having to do with physics, closely or remotely, should keep this book near to his elbow.

GEORGE F. STRADLING.

HANDBOOK OF ENGINEERING MATHEMATICS, by Walter E. Wynne, B.E., and William Sparagen. New York, D. Van Nostrand Company, 1916. 200 pages, 4 x 6½ inches, 113 illustrations, with tables. Price, $2 net.

A compendium of information bearing upon the subjects with which the engineer has to deal in professional practice is a well-recognized necessity, and in recent years the number of handbooks available for this purpose has considerably increased. These books, containing a large collection of engineering data, include a brief section on pure mathematics, and many users doubtless wish that this feature were presented in greater detail. The volume, in keeping with its title, covers this ground much more thoroughly and will appeal to those who require a greater amount of mathematical data than is contained in the customary handbook.

While mainly devoted to mathematics, the work contains brief chapters on theoretical mechanics, mechanics of materials, hydraulics, and electricity. It is stated in the introduction that it is primarily intended for students in engineering as a convenient reminder of things easily forgotten. Practising engineers are probably in greater need of a convenient reminder than students who have the facilities of the college library. The chapters on applications are scarcely full enough to meet the needs of the former class of users. Besides, the inclusion of this material takes up space that might better be devoted to a greater number of mathematical theorems. For instance, the chapters in algebra and analytic geometry are quite brief and might be considerably amplified. The chapters on the calculus and differential equations, on the other hand, embrace a very satisfactory outline of the subjects and cover the ground in considerable detail. The purpose of its authors perhaps justifies the plan adopted, but to satisfy the users who have had the opportunity of examining other books on engineering mathematics, the work might well be double its present volume. A bibliography might also be included. Nevertheless it contains much valuable information in just that readily available and compact form that will save both time and energy.

LUCIEN E. PICOLET.

THE "MECHANICAL WORLD" POCKET DIARY AND YEAR BOOK FOR 1917. Baltimore, The Norman, Remington Company, 30th year of publication. 332 pages, illustrated, 4 x 6 inches, cloth. Price postpaid, 40 cents.

Thirty years ago, when the Pocket Dairy was first issued, there was little literature of that kind available in English. There are now several handbooks covering each of the various departments of engineering. Despite the advent of these, the Diary, in the field of mechanical engineering, still finds a wide sphere of usefulness; perhaps because of its low cost, but more probably because of the evident discrimination shown in compiling the subject-matter. Exclusive of index and advertisements, there are only 265 pages of printed matter, but in this relatively small space a very large amount of data of the kind required by the machine designer has been condensed. The book has been brought up to date by the addition of a section on the heat treatment of steel and a number of new tables. British standards predominate.

LUCIEN E. PICOLET.

PUBLICATIONS RECEIVED.

Explosives, by Arthur Marshall, A. C. G. I., F. I. C., F. C. S., Chief Inspector, Indian Ordnance Department. Second edition. Vol. 1, History and Manufacture. 407 pages, illustrations, quarto. Philadelphia, P. Blakiston's Son & Company, 1917. Price, for two volumes, $16.

The Method of Enzyme Action, by James Beatty, M. A., M. D., D. P. H., with introduction by Prof. E. H. Starling, M. D., Sc. D., F. R. S. 143 pages, 8vo. Philadelphia, P. Blakiston's Son & Company, 1917. Price, $1.75.

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CURRENT TOPICS.

Expenditure of Ammunition. ANON. (*The Field Artillery Journal,* vol. vii, No. 1, p. 31, January-March, 1917.)—That the expenditure of field artillery ammunition in the present war has been enormous, and beyond any conception based upon previous experience, is well known, but, like many other matters of importance, exact data have not generally been available. The following, taken from General Sixt von Arnim's report concerning the battle of the Somme, July, 1916, are extremely interesting, in that they give the maximum expended in any one day of 24 hours, and the average daily expenditure during the entire month of July, 1916:

1. Maximum artillery ammunition expended in any one day of 24 hours:

77-mm. field gun	322 rounds per gun
105-mm. field howitzer	479 rounds per gun
150-mm. howitzer	233 rounds per gun
105-mm. gun	321 rounds per gun
210-mm. mortar	116 rounds per gun

2. Daily average (24 hours) during July, 1916:

77-mm. field gun	145 rounds per gun
105-mm. field howitzer	170 rounds per gun
150-mm. howitzer	119 rounds per gun
105-mm. gun	118 rounds per gun
210-mm. mortar	51 rounds per gun

3. One field battery (howitzers) expended in one day 3500 gas shells.

The actual number of guns in action is not known. The best information gives a probable number of one field gun, exclusive of heavy types, for every 20 yards of front. The approximate frontage of the Somme battle was 40 miles, so that the number of field guns engaged numbered in the vicinity of 3500. Each gun fired 145 projectiles per day, or a total of 4495 for the month, and the total fired becomes 15,732,500. The German 77-mm. projectile weighs seven kilogrammes, or 15.4 pounds, so that the total weight fired was 242,280,500 pounds, or 121,140.25 tons. The computed weight of the heavy artillery ammunition would probably more than double this amount.

Such figures only serve to demonstrate the vastness of the conflict in Europe, and to point out to us the enormous difficulties of ammunition supply, both in manufacture and carriage to the guns. And we must remember that in the battle of the Somme the Germans were on the defensive and lost ground, so that the above expenditure does not even represent a successful defence. The figures also point out the difficulties in the way of a rapid advance after a line of fortifications has been pierced. First the guns must be moved forward, in itself a slow and difficult task, over the broken and shell-torn ground; then, over the same ground, roads must be constructed, or the light field railway must be laid and a new ammunition supply established. The time necessary for these operations is much longer than that necessary for the defence to establish a new trench line, and the attacking infantry in modern war dare not go beyond the support of its artillery.

The Electrolytic Pickling of Steel. M. DeK. THOMPSON and O. L. MAHLMAN. (*Proceedings of the American Electrochemical Society,* May 2–5, 1917.)—All iron and steel objects which in the process of manufacture have been heated in the air are covered with "fire scale," which is an oxide of iron. This has to be removed before the surface can be plated or galvanized. The usual practice has been to immerse the objects in some acid until the scale is removed by the hydrogen formed by the action of the acid on the iron beneath the scale, which it reaches through the cracks in the scale. The action which would be expected if a sheet of iron covered with scale were used as a cathode in an acid solution is a reduction from a higher to a lower oxide. This oxide would be dissolved by the acid. There would also probably be a certain amount of chemical action between the iron under the scale and the acid, as in the purely chemical treatment. It is this action which the electrochemical process attempts to avoid as much as possible.

The method of comparing the two operations consisted in treating two similar mild steel plates by the two methods until their appearance showed that the pickling was completed. The scale was produced by heating for two to eight minutes pairs of plates in a muffle furnace and cooling them in air. One of these was then treated by the chemical method, the other by the electrolytic method. In two experiments the saving effected, in acid and amount of iron removed, for every 2000 pounds of iron, including the cost of power, was about $70, and in a third about $50. While these results differ considerably and are probably due to accidental differences in the quality of the scale, they point to important economies that may result from the adoption of the electrolytic method.

Manufacture of Rifles for the United States Forces. S. TRASK. (*Arms and The Man,* vol. lxii, No. 5, p. 83, April 28, 1917.)—When war was declared and it became certain that the national army would assume, numerically, great proportions, the ordnance experts of the army immediately realized that the output of Springfield rifles from the Springfield and Frankford arsenals would by no means meet the increased demand, or even keep pace with the recruiting. To meet just such an emergency, efforts have been made in Congress to secure the necessary appropriation for increasing the output of the standard arm. It was realized, however, that much time would be consumed in the manufacture of the special tools required and that there would still be a shortage of rifles. It was therefore the consensus of opinion that an emergency arm should be selected.

At the present time thousands of the British Enfield, the Russian Nagant and the French Lebel rifles are being turned out every day in the United States, together with some less modern types. That source of supply being immediately available, it has been decided to select one of these, chambered to take service ammunition, as the emergency rifle of the United States. Because a greater number of factories are equipped to manufacture the British Enfield and the output is greater than any other, it being possible within six months to produce between 6000 and 11,000 a day, this arm will probably be adopted. Two patterns of the Enfield are now in use in the British Army. The newer so-called " Model 1914 " will probably be the one chosen if the United States definitely decides to manufacture this arm. The rifle is considerably heavier than the Springfield, weighing 9 pounds 5 ounces, the barrel being 26 inches long, against the Springfield weighing 8 pounds 12 ounces, with a 24-inch barrel. In the British pattern—the kind now being manufactured in the United States—the calibre is 0.303 inch, and the barrel is rifled with five grooves, with a pitch of one turn in 10 inches. The Springfield has four grooves with the same pitch. The rifle is loaded by a charger holding five rounds. No cut-off is provided. The bottom of the magazine comes flush with the stock, and is removable for cleaning and repair.

Detecting the Presence of Submarines by Means of Aircraft. H. WOODHOUSE. (*Flying,* vol. vi, No. 4, p. 271, May, 1917.)—The usual evidence of a submarine's presence is the wake of the periscope. This wake cannot easily be seen from ships, but can always be clearly seen from aeroplanes. The aviator is not troubled by the refraction of light which interferes with vision from a ship, and at a height of 1000 to 1500 feet, with a range of vision of many miles, the whitish wake of the periscope is clearly visible against the dark surface of the waters, even in cases where the sea is fairly rough and white-caps are showing. In clear weather an aviator at a height of 1000 to 1500 feet can see a submarine under water when the water is clear, even when the submarine is at a depth of 100 feet; in less clear water the submarine can be seen at a depth of 20 to 30 feet.

Present-day submarines are so large that they not only can be detected through the contrast which they make against their surroundings in the water, but also through the foamy wake at the stern, which is clearly visible by contrast. Exhaustive experiments have been made in painting submarines so as to make them less visible when they are under water. They can be made less visible by painting them in colors that blend well with the color of the water, but it is hardly possible to so paint the large fleet of submarines and ocean-going super-submarines, which are used for long cruises, in such a way as to blend with the water and conditions existing in different places in which they are cruising. The smaller coastal type submarine, which is used entirely for coast defence and does not have to make long cruises, can be painted more effectively to blend with the color of the water in which it operates. Nothing, however, can be done to eliminate the foamy wake of the periscope, and if the periscope were eliminated the submarine would have to come close to the surface, where it would make a better target for the aviator.

Many submarines escape attack because aviators cannot distinguish hostile from friendly submarines and make no attempt to destroy them when in doubt as to their identity. Marking submarines does not afford a solution, because the enemy can adopt the markings and carry on its work of destruction under disguise. Hundreds of kite balloons have been used as lookouts for submarines in the great war. These balloons are sent up from barges or kite balloon ships, and are sent up to a height of 1000 to 2000 feet, where they stay throughout the day, the observers scanning the surface of the water, looking out for submarines. When they discover a submarine or doubtful ship, they summon aeroplanes, destroyers, or submarine chasers by wireless.

The Split-phase Motor. F. S. DELLENBAUGH, JR. (*The Electric Journal,* vol, xiv, No. 5, p. 198, May, 1917.)—It is difficult to realize, now that single-phase motors are manufactured by the hundred thousand, that not many years ago they were considered an engineering curiosity and even after coming into practical use were uncertain in action. To understand why this type of motor is called " split-phase " and why a switch is necessary, its early development must be understood. To Tesla belongs the credit of conceiving the ideas leading to the experiments which resulted in the first successful induction motor. The first alternating-current motor was a two-phase machine, which was built after he discovered that the proper arrangements of windings upon the starter for each of the two phases resulted in a whirling flux. Any conductors in this whirling field are dragged around very much like leaves in a whirlwind. This principle of a revolving magnetic field is the basis for the operation of all induction motors. It is necessary to have two sources of magnetizing current having a difference of phase in order to produce this rotating field. Therefore it was with considerable surprise that Tesla accidentally discovered that his two-phase motor would continue to run if one phase were disconnected after it has reached full speed. In other words, he accidentally obtained the first single-phase motor.

Although it was not clear at the time just why the motor ran, later it was discovered that the magnetic reaction of the rotating parts furnished the second magnetizing current which produced the rotating field. This second component of the magnetizing field is absent when the motor is not moving; an oscillating instead of a rotating effect is then the only result. Evidently this gives zero starting torque, and therefore the next problem was the development of some means of starting this newly-discovered single-phase motor. The most obvious method of starting the machine was to employ some external device which would give two-phase characteristics to a single-phase power circuit. This actually was done by means of a device called a "phase splitter," consisting of two independent circuits connected to the same single-phase line. One of these circuits contained a condenser, and hence had a leading power-factor, while the other included an inductance coil and had a lagging power-factor. When connected to the two windings of a two-phase induction motor, these two circuits gave approximately the same effect as a two-phase current, and would start the machine with somewhat reduced torque. After the motor was up to speed, one motor winding was disconnected and the phase-splitting device was cut out of the circuit.

This system worked satisfactorily, but was never tried out on a large scale commercially, because the phase-splitter was large and expensive, required hand operation, and did not give very large starting torque. The installation of the phase-splitting device in the motor itself was the next step. Engineering development finally produced the present design, in which two windings are still employed with the same mechanical relations to each other that are used in the two-phase motors, but having quite different electrical characteristics. The one winding has a low resistance and a high reactance, while the other has a high resistance and a low reactance. The result is that the power-factor is much closer to unity in one winding than in the other, and the phase displacement is sufficient to give the required whirling magnetic effect, resulting in a starting torque. The high-resistance winding, called the starting winding, if allowed to remain in the circuit, will generate enough heat to destroy the insulation. This heat is the direct result of the high resistance, but if the resistance is lowered the starting torque is proportionally decreased, and at best is only equal to full-load torque. The necessity for removing the starting winding from the circuit as soon as possible is inherently unavoidable in the design of this type of motor. Since the point at which this winding should be disconnected corresponds to a definite point on the speed-torque curve, the obvious way of producing the desired effect is by a centrifugally operated switch. This is the scheme that was adopted, and it has been developed to a very high state of perfection.

Canadian Asphaltic Sand. Anon. (*Scientific American,* vol. cxvi, No. 13, p. 326, March 31, 1917.)—Since the first explorer descended the Athabaska River, upwards of 150 years ago, the existence in the northern part of the Province of Alberta of deposits of asphaltic sand has been recognized. This material consists of approximately 15 per cent. of high-grade bitumen and 85 per cent. of silicious sand. That the deposits were of large extent was evident, but until recently little was definitely known regarding their true economic importance. For many years the remote geographical position of the deposits and the lack of transportation facilities effectually prohibited any attempt at actual development. With new railroads serving this district nearly completed, however, the difficulty of transportation will have been removed. The important outstanding features presented by these deposits are: (1) They represent the largest known deposits of solid asphaltic material; (2) the deposits are as yet totally undeveloped; (3) at the present time every ton of asphalt used in Canada is imported from foreign countries. The areal extent of the deposits is probably not less than one thousand square miles, and the average thickness is upwards of 100 feet. When adequate markets and transportation facilities become available there seems reason to believe important developments may be expected.

Recently the Mines Branch of the Canadian Department of Mines has undertaken an investigation not only of the deposits themselves, but also of methods best adapted to the commercial treatment of the crude bituminous sand. The results of this work suggest the use of the bituminous sand in a more or less crude form in the surfacing of streets and highways; to separate the asphalt or bitumen from the crude material in order to derive a more or less pure product; or to destructively distil the crude bituminous sand for the purpose of obtaining crude petroleum therefrom. Considering the absence of developed petroleum fields in Canada, such distillation could be undertaken under exceptionally favorable conditions. A study of possible separation and distillation methods is being made at the Mellon Institute of Industrial Research in Pittsburgh. Though details are not yet available, a process for economically effecting the separation has been developed. It is of interest to note that practically the entire area of bituminous sand is under government reserve. There is reason to believe, however, that within a reasonable time this reserve will be removed and provision made whereby private individuals or companies may acquire areas for development.

Artificial Fertilizers. E. J. RUSSELL. (*Journal of the Society of Chemical Industry*, vol. xxxvi, No. 5, p. 250, March 15, 1917.)—Artificial fertilizers are simple salts which are added to the soil to help in the nutrition of plants; they are called "artificial" because they have usually undergone some manufacturing process. They are of three classes: Nitrogen compounds, phosphates, and potassium compounds. It is also useful to add a fourth—organic matter. Almost anything containing these constituents will serve, provided that the substance is not toxic to the plant and that it is capable of going into solution in the soil water directly or as the result of decomposition in the soil, so that it can enter the plant roots. In practice, however, a third condition is essential: the price must be sufficiently low, and this rules out so many substances that the actual list is short. Grouped under the four classes named, these are: *Nitrogenous.*—Nitrate of soda, sulphate of ammonia, calcium cyanimide, and calcium nitrate. *Phosphatic.*—Superphosphate, basic slag, and bone manures. *Potassic.*—The Stassfurt salts. *Organic.*—Excretions from animals fed on imported feeding stuffs, guano, fish and meat meals, and other manufacturing residues.

These four classes have very different properties, and they are in no sense interchangeable. In laboratory experiments, sand cultures, etc., all the three first-named constituents are necessary for plant growth, but in field practice the soil supplies something, so that artificial fertilizers are needed to make up deficits or to increase production. The only way of finding out what is needed is by actual trial: the hope once entertained that soil analysis would give a short and easy indication of the deficit has not been realized. Moreover, each of these different classes, besides contributing to the general nutrition of the plant, has certain specific effects which can be discovered only by trial.

The fertilizers are mainly simple salts (in other words, electrolytes), and the soil owes most of its important properties to its colloidal constituents. Electrolytes profoundly change some of the properties of colloids, and the effects cannot always be predicted; usually they have to be discovered by experiment. Further, some fertilizers undergo remarkable changes in soil. Nitrate of soda, for example, changes to carbonate of soda, which, as an alkali, has a strong deflocculating action in the clay, thereby greatly modifying the texture of the soil. Sulphate of ammonia gives rise under certain conditions to an acid which changes the reaction of the soil, and a change in reaction of the medium may profoundly affect the growth of organisms and of plants. In dealing with artificial fertilizers, therefore, it is necessary to take into account not only their effect on the plant and their price, but also the changes that they are likely to undergo in the soil and the effects the products will have on the soil and on the plant. These are so complex that they can usually be determined only by direct trial.

Portable Track for French Strategic Railways. ANON. (*The Iron Trade Review,* vol. lx, No. 12, p. 669, March 22, 1917.)—The abnormal traffic of heavy motor trucks over French roads in proximity to the fighting line for more than two years has rendered them almost impassable in many places. In addition to this destructive effect, the roads, like the battlefields, have been furrowed and plowd by bursting shells until all semblance to highway or even lane is blotched out for miles. The problem of transporting the heavy supplies of ammunition, food, and clothing over the shell-torn fields to the points of action has been greatly simplified by the use of portable track. France is approximately as large as the states of Montana and Ohio combined; the part of the country confined to actual warfare is perhaps one-tenth of this area, yet within that small section there is a network of more than 2500 miles of this narrow-gauge track.

The track is made in convenient lengths—1¼, 2½, and 5 metres—which may be readily connected to curved sections, turntables, and numerous types of switches and cross-overs. The three lengths have three, five, and eight ties, respectively. The gauge is 60 centimetres. The rails, which are rolled to a special size designated by the French Government, weigh 20 pounds per yard. The general appearance of the rail section resembles the standard A. S. C. E. section 16. The ties weigh about 20 pounds each, and withstand a bending stress of more than 4500 pounds. They are pressed hot from 3/16-inch sheet stock into a dished form, measuring 6 × 44 inches, with a ¾-inch rim. The appearance of the sections and the ease with which they may be laid remind one of the very neat toy track and train assortment now in vogue. But this track is built to withstand severe service; it is laid by experienced track layers and carries carload after carload of heavy shells and other supplies. The trains are operated by double-ended Baldwin locomotives. A large percentage of this portable track is made at the plant of the Lakewood Engineering Company, Lakewood, Ohio. At the present time the Lakewood Company is producing from three to four miles of track a day, requiring 80 to 100 tons of rails and 75 tons of tie stock. The contracts completed and active involve more than 8000 tons of this portable track.

Gelatinobromide Ferrotype Photographic Plates. ANON. (*Revue Scientifique*, vol. 55, No. 5, p. 151, February 24–March 3, 1917.)—The collodion photographic negative possesses the peculiar property of appearing as a positive when viewed by reflected light with the plate backed by a black surface. The best-known application of this positive process is embodied in the so-called "tintypes" in vogue some years ago. These tintypes were produced by supporting the sensitized collodion film upon a thin sheet-iron plate coated with black japan varnish. The black surface showing through the transparent parts of the film produces the shadows, while the light-colored but opaque silver particles form the high lights.

The inconveniences of the wet collodion process are well known, and, although dry collodion plates of satisfactory keeping quality have been made, adequate sensitiveness to meet modern requirements has not been secured. The first gelatin ferrotype plates failed to give a sufficiently light-colored deposit for the proper rendering of the high lights, and bleaching with bichloride of mercury was employed with a considerable degree of success. The lack of permanency of the bichloride bleach, however, proved a serious obstacle to this expedient. By means of special emulsions, Messrs. Lumière have succeeded in producing gelatine ferrotype plates of sufficient speed that yield images comparable in brilliancy to collodion plates and require no other treatment than developing and fixing. It has also been found possible to simplify manipulation by combining the developing and fixing bath. It is suggested that such plates may prove of value in radiographic field operations.

The Corrosion of Cast Iron and its Bearing on the Electrolytic Theory of Corrosion. E. A. RICHARDSON and L. T. RICHARDSON. (*Proceedings of the American Electrochemical Society,* May 2–5, 1917.)—The field of cast iron as regards its usefulness as a rust-resisting metal has been much neglected, and to-day remains almost unexplored. This, no doubt, is due in part to the fact that only in the last few years has the resistance of irons to corrosion been considered one of their important properties. The efforts to improve materials for structural and other purposes have been directed toward the production of a material having superior physical properties, such as tensile strength with a great reliability. This is the reason that cast iron, once extensively used for structural purposes, has been replaced by steel. However, for many other purposes cast iron is still used in enormous quantities in places exposed to corroding influences. Many instances are known where cast-iron objects have lasted many years, even centuries, and have remained in good condition when exposed to corrosive influences, and that when used underground cast iron is usually superior to other kinds of iron.

According to the electrolytic theory of corrosion, cast iron, being less pure and more heterogeneous than steel or pure iron, should rust faster than either of these. Three pieces of these materials were exposed to rusting influences for seven months, then cleaned and weighed. Pure iron corroded least, cast iron 25 per cent. more, and steel 100 per cent. more. The electrolytic theory of corrosion does not explain these results. While it may be true that the initial rusting is largely electrolytic in character, other factors, such as the adherence of the rust and protection given thereby to the metal, come into operation and outweigh any electrolytic corrosion.

PRESS OF
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INDEX TO VOL. 183.

Acoustic efficiency of fog-signal machinery (King), 259
Address to graduating class, The Franklin Institute School of Mechanic Arts (Levy), 755
Aeronautics: Equivalent mass in rigid dynamics with applications to gyroscopes and propellers (Zahm), 207
  Scientific research for national defense as illustrated by the problems of aeronautics (Squier), 35
Air, Electric strength of (Whitehead), 433
American industry, Chemistry and (Cushman), 557
Anderson, Robert J.: Ferromanganese in the iron and steel industry, 579
Animals, Production of light by (Dahlgren), 79, 221, 323, 593, 735

Bleininger, A. V.: The development of the ceramic industries in the United States, 127

Book Notices:
  Blasdale, W. C.: Principles of quantitative analysis, 522
  France, Bureau des Longitudes, Annuaire pour l'An 1917, 524
  Gas Chemists' Handbook, 652
  Hawk, P. B., Practical physiological chemistry, 522
  International Military Digest Annual, 1916, 651
  Marshall, C. E.: Microbiology, 523
  "Mechanical World" pocket diary and year book for 1917, 795
  Northrup, E. F.: Laws of physical science, 793
  Noyes, W. A.: Organic chemistry for the laboratory, 115
  Waddell, J. A. L.: Bridge engineering, 521
  Wynne and Sparagen: Handbook of engineering mathematics, 794
Bown, Ralph: The characteristics of iron in high frequency magnetic fields, 41

Cable telegraphy, Multiplexing in (Squier), 575
Ceramic industries in the United States, Development of the (Bleininger), 127
Chemistry and American industry (Cushman), 557
Coke, By-product (Ramsburg and Sperr), 391
Coking operations (Ramsburg and Sperr), 391
Colors of mother-of-pearl (Pfund), 453
Current Topics, 33, 60, 100, 106, 117, 167, 168, 228, 233, 236, 238, 253, 254, 286, 322, 351, 352, 356, 366, 367, 431, 432, 451, 452, 464, 508, 511, 512, 525, 526, 775, 776, 778, 782, 785, 786, 796,
Cushman, Allerton S.: Chemistry and American industry, 557

Dahlgren, Ulric: The production of light by animals, 79, 221, 323, 593, 735.
Dielectric losses in insulating materials (Skinner), 667
Dynamics, rigid: The equivalent mass in, with applications to gyroscopes and propellers (Zahm), 207

Eastman Kodak Company Research Laboratory, Notes, 235, 499, 635, 777
Electric arc, Luminous efficiency of the radiation from the (Karrer), 61
Enzymes in the fermentation industries (Wallerstein), 531, 715
Equivalent mass in rigid dynamics, with applications to gyroscopes and propellers (Zahm), 207
Fermentation. Enzymes in the fermentation industries (Wallerstein), 531, 715
Ferromanganese in the iron and steel industry (Anderson), 579
Fertilizers. Organic nitrogen compounds of (Lathrop), 169, 303, 465
Fog-signal machinery, on the acoustic efficiency of (King), 259
Franklin Institute:
  Library Notes:
    111, 247, 362, 518, 648, 789

Membership Notes, 109, 244, 360, 515, 646, 789
President's report, September 30, 1916, 240
School of Mechanic Arts, Address to graduating class (Levy), 755
Annual report of the Director, 1916–1917, 639
Science and the Arts Committee, abstract of proceedings of meetings: December 6, 1916, 108; January 3, 1917, 243; February 7, 1917, 359; March 7, 1917, 513; April 4, 1917, 644; May 2, 1917, 788
Sections, Proceedings of Meetings, 108, 244, 359, 514, 645, 788
Stated Meeting, Proceedings: December 20, 1916, 107; January 17, 1917, 239; February 21, 1917, 357; March 21, 1917, 513; April 18, 1917, 639; May 16, 1917, 787

General Electric Company, Research Laboratory, Notes, 101
GILBERT, F. B., and ALFRED B. HITCHINS: A shutter testing machine, 73
Gyroscope. Equivalent mass in rigid dynamics, with applications to gyroscopes and propellers (Zahm), 207

High-pressure investigations, Some aspects of recent (Johnston), 1
HITCHINS, ALFRED B., and F. B. GILBERT: A shutter testing machine, 73

Illumination. Fundamental principles of good lighting (Nutting), 287
Industrial research. Independent laboratories in the engineering industries (Sharp), 221
Insulating materials, Dielectric losses in (Skinner), 667
Iron and steel industry, Ferromanganese in the (Anderson), 579
Iron, Characteristics of, in high frequency magnetic fields (Bown), 41

JOHNSTON, JOHN: Some aspects of recent high-pressure investigation, 1

KARRER, ENOCH: The luminous efficiency of the radiation from the electric arc, 61
KING, LOUIS VESSOT: On the acoustic efficiency of fog-signal machinery, 259

Laboratories, independent in the engineering industries (Sharp), 221
LATHROP, ELBERT C.: The organic nitrogen compounds of soils and fertilizers, 169, 303, 465
LEVY, LOUIS EDWARD: Address to the graduating class, The Franklin Institute School of Mechanic Arts, 755
Light, The production of, by animals (Dahlgren), 79, 221, 323, 593, 735
Lighting, Fundamental principles of good (Nutting), 287
Luminous efficiency of the radiation from the electric arc (Karrer), 61

Magnetic fields, high-frequency, Characteristics of iron in (Bown), 41
Massachusetts Institute of Technology, Electrical Engineering Department, Notes, 237, 509, 783
Mother-of-pearl, Colors of (Pfund), 453
Multiplexing in cable telegraphy (Squier), 575

National Research Council, 759
Nela Research Laboratory, Notes, 353, 633, 773
NUTTING, P. G.: The fundamental principles of good lighting, 287

Organic nitrogen compounds of soils and fertilizers (Lathrop), 169, 303, 465

PFUND, A. H.: The colors of mother-of-pearl, 453
Photography: A shutter-testing machine (Hitchins and Gilbert), 73
Publications received, 116, 252, 365, 524, 652, 795

RAMSBURG, C. J., and F. W. SPERR, JR.: By-product coke and coking operations, 391

Scientific research for national defence (Squier), 35
SHARP, CLAYTON H.: Independent laboratories in the engineering industries, 221
Shutter-testing machine (Hitchins and Gilbert), 73
SKINNER, C. E.: Dielectric losses in insulating materials, 667
Soils, Organic nitrogen compounds of (Lathrop), 169, 303, 465

SPERR, F. W., JR., and C. J. RAMSBURG: By-product coke and coking operations, 391
SQUIER, GEORGE O.: Multiplexing in cable telegraphy, 575
SQUIER, GEORGE O.: Scientific research for national defence, as illustrated by the problems of aeronautics, 35

United Gas Improvement Company, Physical Laboratory, Notes, 779
U. S. Bureau of Standards, Notes, 95, 229, 349, 625, 767

Voltage, high, Methods of measuring (Whitehead), 433

WALLERSTEIN, LEO: Enzymes in the fermentation industries, 531, 715
WHITEHEAD, J. B.: The electric strength of air and methods of measuring high voltage, 433

ZAHM, A. F.: The equivalent mass in rigid dynamics, with applications to gyroscopes and propellers, 207

THE FRANKLIN INSTITUTE

ANNOUNCEMENTS

MEETINGS

COMMITTEE ON SCIENCE AND THE ARTS. First Wednesday of each month, 8 P.M. (except July and August).

BOARD OF MANAGERS. Second Wednesday of each month, 3.30 P.M.

INSTITUTE. Third Wednesday of each month (except June, July, August and September), 8 P.M.

SECTION MEETINGS. Thursday Evenings (except week of Institute Meeting), 8 o'clock. October 1 to April 30.

PAGE
Officers for 1917 xii
Membership xiii
Awards and Premiums xiv
  John Scott Legacy, Medal and Premium . . xiv-xvi
  Boyden Premium xvii
  Potts and Longstreth Medals xviii
Library iv
Journal and Indices x
School of Mechanic Arts . . . . . Fourth cover

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Members are particularly requested to inform the Secretary of changes of address.

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This method of separating the *body holding* the principal of the various funds from the Board of Managers, the *spending body*, is an original idea of The Franklin Institute and it is hoped it will appeal to friends who may desire to create funds to further the objects of the Institute, and the various branches of science in which they may be interested.

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Terms and Privileges.

THE MEMBERSHIP OF THE INSTITUTE is divided into the following classes, viz.: *Resident Members, Stockholders, Life Members, Permanent Members, Non-resident and Associate Members.*

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PERMANENT MEMBERS.—The Board of Managers may grant to any one who shall in any one year contribute to The Institute the sum of One Thousand Dollars a permanent membership, transferable by will or otherwise.

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RESIGNATIONS *must be made in writing, and dues must be paid to the date of resignation.*

For further information and membership application blanks address the SECRETARY of THE INSTITUTE.

THE FRANKLIN INSTITUTE AWARDS

Notice is hereby given that THE FRANKLIN INSTITUTE, through its Committee on Science and the Arts, will recommend the award of

THE JOHN SCOTT LEGACY MEDAL AND PREMIUM

To

THOMAS BILYEU

of Terre Haute, Indiana

for his Inventions embodied in the

INTERNATIONAL MONEY MACHINE

Any objection to the above award based on evidence of lack of merit should be communicated within three months of the date of this notice to the Secretary of THE FRANKLIN INSTITUTE, Philadelphia.

R. B. OWENS,
Secretary

HALL OF THE INSTITUTE
April, 1917

THE FRANKLIN INSTITUTE AWARDS

Notice is hereby given that THE FRANKLIN INSTITUTE, through its Committee on Science and the Arts, will recommend the award of

THE JOHN SCOTT LEGACY MEDAL AND PREMIUM

To

LUCIEN I. YEOMANS

of Chicago, Illinois
for his

METHOD OF MACHINE CONSTRUCTION

Any objection to the above award based on evidence of lack of merit should be communicated within three months of the date of this notice to the Secretary of THE FRANKLIN INSTITUTE, Philadelphia.

R. B. OWENS,
Secretary

HALL OF THE INSTITUTE
June, 1917

THE FRANKLIN INSTITUTE AWARDS

THE JOHN SCOTT LEGACY MEDAL AND PREMIUM

THE City of Philadelphia holds in trust under the legacy of John Scott, of Edinburgh, a sum of money the interest of which is to be used for the encouragement of "ingenious men and women who make useful inventions." **The legacy provides for the distribution of a Medal, inscribed "To the Most Deserving," and Money Premium in the sum of $20 to such persons whose inventions shall merit the same.** The examination of the inventions submitted for the Medal and Premium has been delegated by the Board of Directors of City Trusts, of the City of Philadelphia, to THE FRANKLIN INSTITUTE. and THE INSTITUTE, under the competent assistance of its Committee on Science and the Arts, undertakes to make investigations free of charge and to recommend for the award all meritorious inventions.

Applications should be addressed to the Secretary of THE FRANKLIN INSTITUTE, from whom all information relative thereto may be obtained.

Pursuant to the regulations for the award of the John Scott Legacy Medal and Premium, THE FRANKLIN INSTITUTE, of the State of Pennsylvania, has under consideration favorable reports upon the applications advertised in this JOURNAL. Any objection to the proposed awards, based on evidence of lack of originality or merit of the invention, should be communicated to the Secretary of THE INSTITUTE within three months of the date of notice.

THE FRANKLIN INSTITUTE AWARDS

THE BOYDEN PREMIUM

URIAH A. BOYDEN, ESQ., of Boston, Mass., has deposited with THE FRANKLIN INSTITUTE the sum of one thousand dollars, to be awarded as a premium to

"Any resident of North America who shall determine by experiment whether all rays of light,* and other physical rays, are or are not transmitted with the same velocity." :: :: :: ::

The following conditions have been established for the award of this Premium:

1. Any resident of North America, or of the West India Islands, may be a competitor for the Premium; the southern boundary of Mexico being considered as the southern limit of North America.

2. Each competitor must transmit to the Secretary of THE FRANKLIN INSTITUTE a memoir describing in detail the apparatus, the mode of experimenting and the results; and all memoirs received by him after the first day of January, one thousand nine hundred and seventeen, will, as soon as possible after this date, be transmitted to the Committee of Judges.

3. The Board of Managers of THE FRANKLIN INSTITUTE shall, before the first day of January, one thousand nine hundred and eighteen, select three citizens of the United States of competent scientific ability, to whom the memoir shall be referred; and the said Judges shall examine the memoirs and report to THE FRANKLIN INSTITUTE whether, in their opinion, any, and, if so, which of the memoirs is worthy of the Premium. And, on their report, THE FRANKLIN INSTITUTE shall decide whether the Premium shall be awarded as recommended by the Judges.

4. Every memoir shall be anonymous, but shall contain some motto or sign by which it can be recognized and designated, and shall be accompanied by a sealed envelope, endorsed on the outside with some motto or sign, and containing the name and address of the author of the memoir. It shall be the duty of the Secretary of THE FRANKLIN INSTITUTE to keep these envelopes securely and unopened until the Judges shall have finished their examination; when, should the Judges be of opinion that any one of the memoirs is worthy of the Premium, the corresponding envelope shall be opened, and the name of the author communicated to THE INSTITUTE. The sealed envelopes accompanying unsuccessful memoirs will be destroyed unopened, in the presence of the Board of Managers.

5. Should the Judges think proper, they may require the experiments described in any of the memoirs to be repeated in their presence.

6. The memoirs presented for the Premium shall become the property of THE FRANKLIN INSTITUTE, and shall be published as it may direct.

The problem has been more specifically defined by the Board of Managers, as follows:—

" Whether or not all rays in the spectrum known at the time the offer was made, namely, March 23, 1859, and comprised between the lowest frequency known thermal rays in the infra-red, and the highest frequency known rays in the ultra-violet, which in the opinion of the Committee lie between the approximate frequencies of 2×10^{14} double vibrations per second in the infra-red and 8×10^{14} in the ultra-violet, travel through free space with the same velocity."

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*An award, made during the year 1907, covered the solution of the problem so far as the transmission of the visible and ultra-violet rays is concerned. It has been directed by the Board of Managers that the balance of the fund be retained, to be awarded to such person as shall demonstrate whether or not the infra-red rays are or are not transmitted with the same velocity as the other rays.

THE FRANKLIN INSTITUTE AWARDS

JOURNAL CONTRIBUTIONS

By a resolution of the Committee on Science and the Arts, made October 5, 1910, all papers published in the Journal of The Franklin Institute will be subject to the award of one of the following Medals—

The Howard N. Potts Gold Medal

The Edward Longstreth Silver Medal

The merits of the several papers appearing in the Journal during any current year will be passed upon by a Special Committee appointed for the purpose.

R. B. OWENS,
Secretary

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